Geomorphometry from SRTM: Comparison to NED

Peter L. Guth
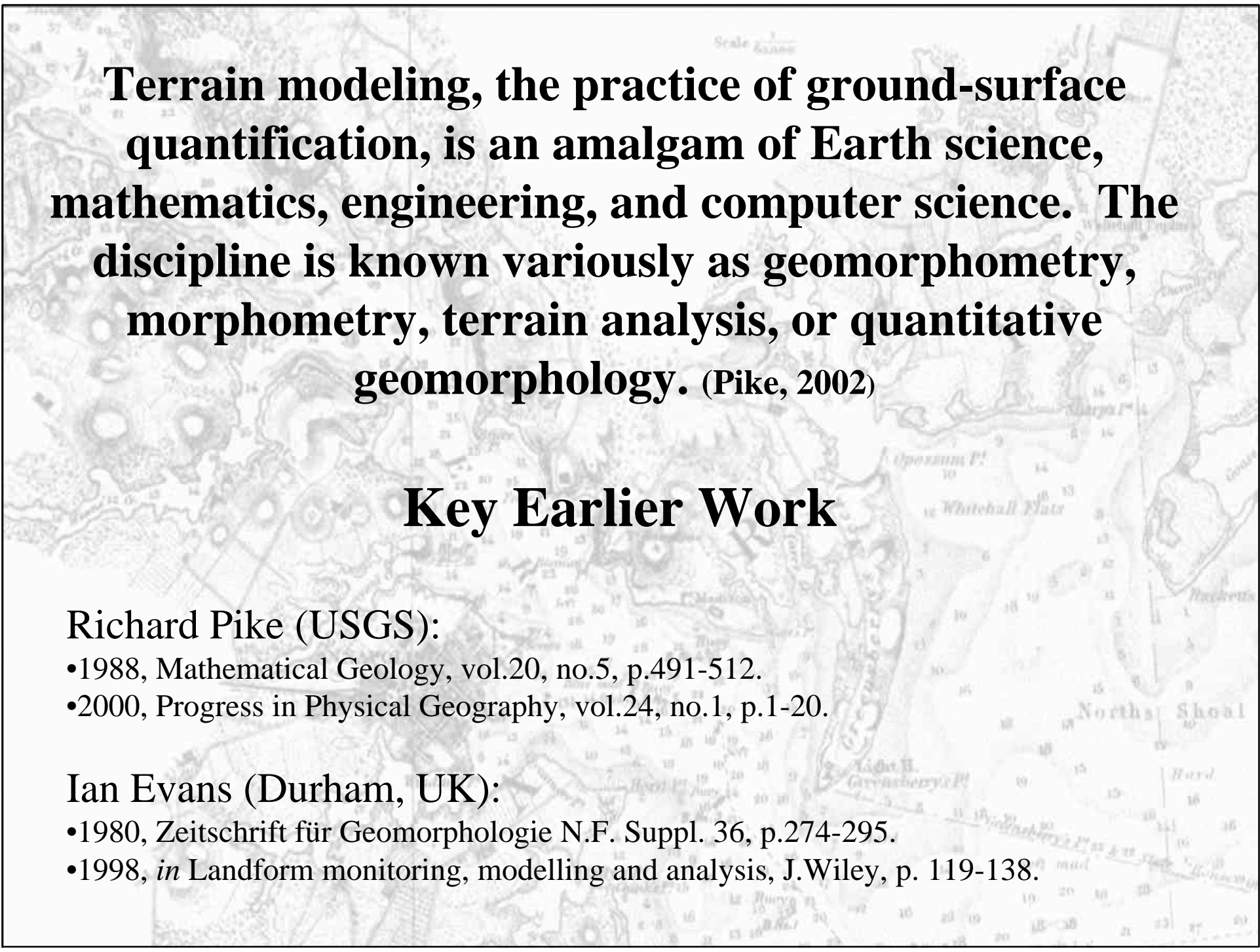
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Shuttle Radar Topography Mission—Data Validation and Applications Workshop

Reston, VA   14 June 2005

Terrain modeling, the practice of ground-surface quantification, is an amalgam of Earth science, mathematics, engineering, and computer science. The discipline is known variously as geomorphometry, morphometry, terrain analysis, or quantitative geomorphology. (Pike, 2002)

Key Earlier Work
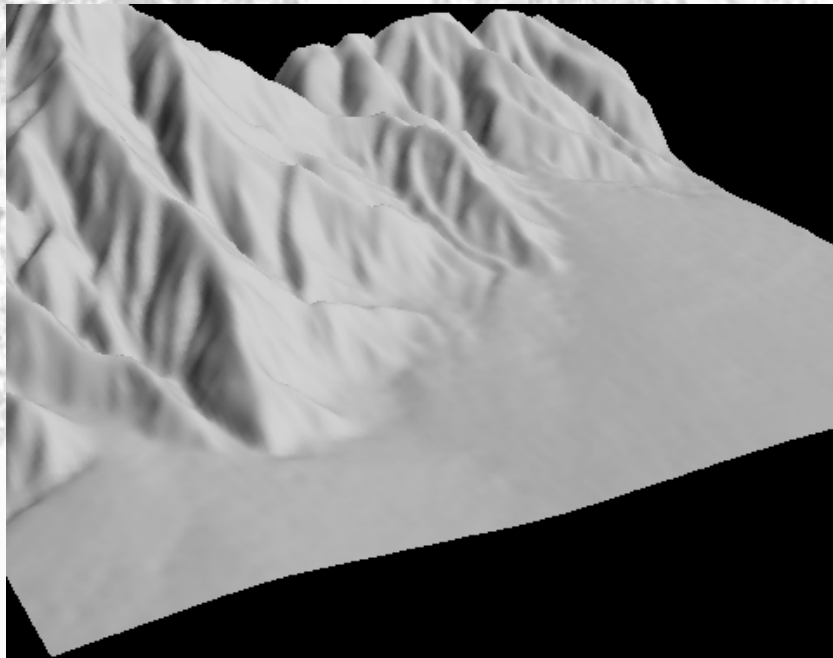
Richard Pike (USGS):
- 1988, Mathematical Geology, vol.20, no.5, p.491-512.
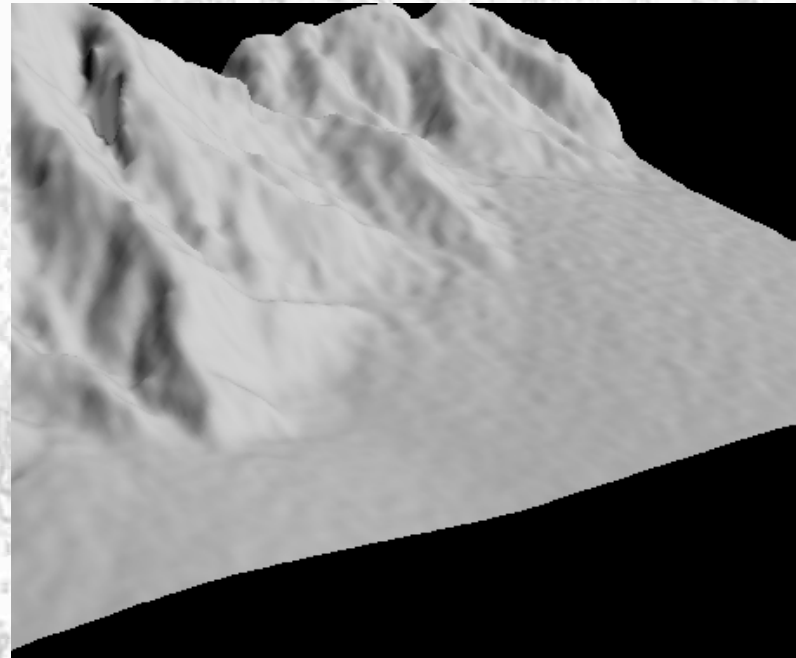- 2000, Progress in Physical Geography, vol.24, no.1, p.1-20.

Ian Evans (Durham, UK):
- 1980, Zeitschrift für Geomorphologie N.F. Suppl. 36, p.274-295.
- 1998, *in* Landform monitoring, modelling and analysis, J.Wiley, p. 119-138.
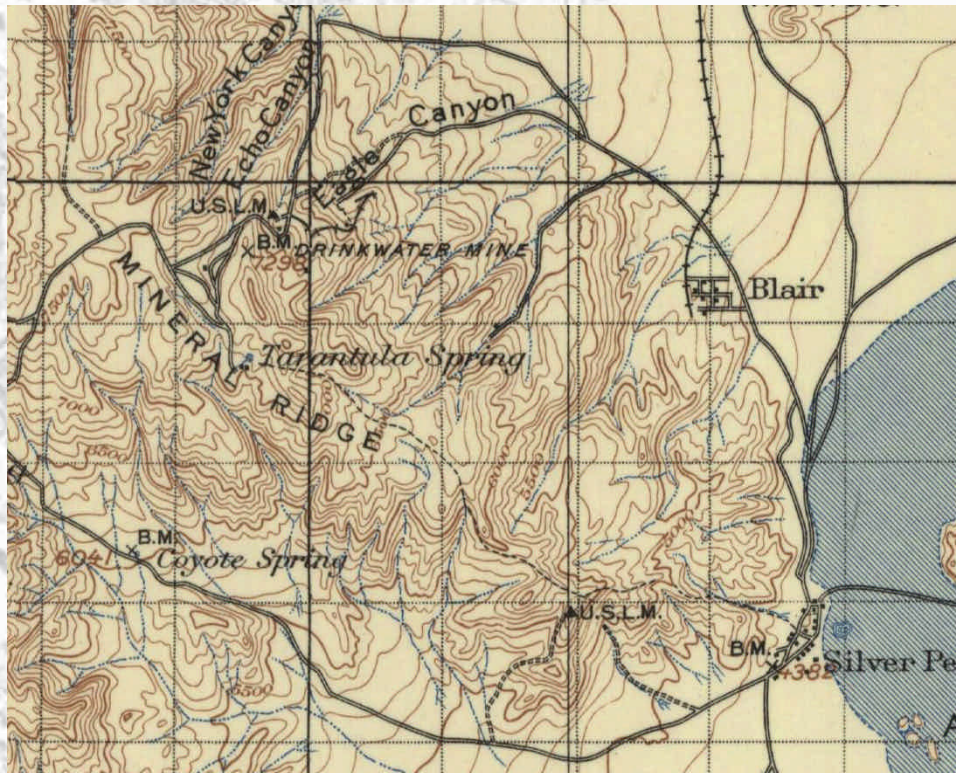
Does a DEM Reflect its Production Method?

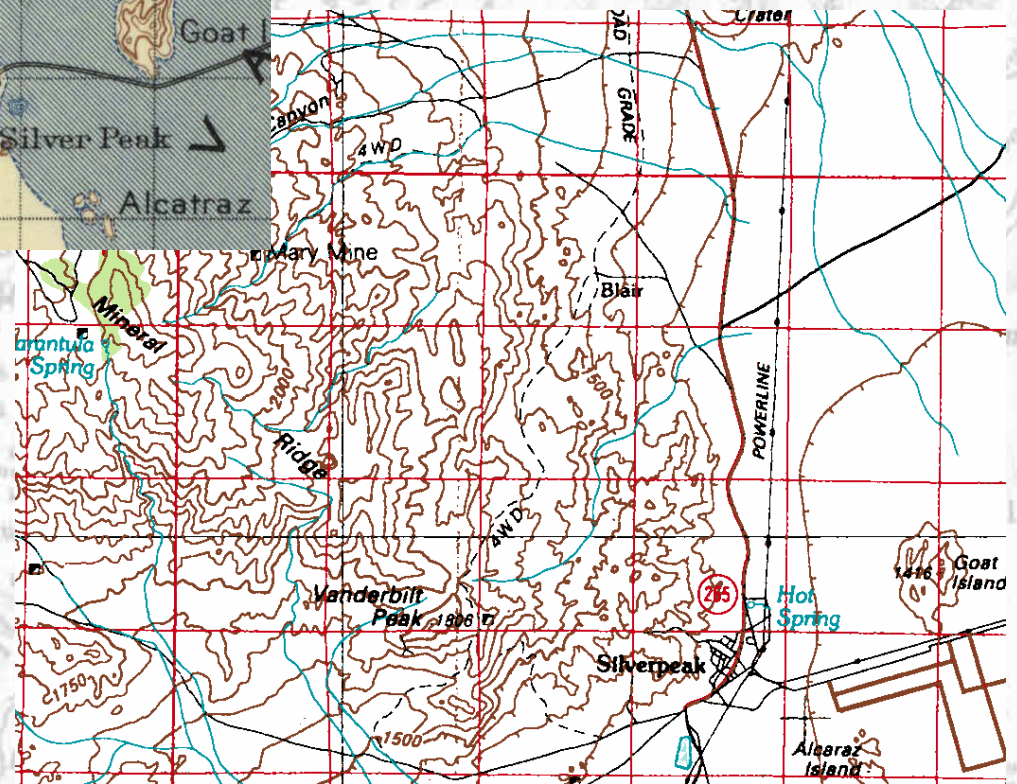**1" NED**   **1" SRTM**

If DEMs differ depending on the production method, do their benefits?

Topo Maps

Plane Table Topo "looked" different

37°30'
118°00' R.36 E.
R.U.Goode, Geographer in charge.
Triangulation by W.T.Griswold.
Topography by W.T.Griswold.
Surveyed in 1897-98.

Methodology

Regional Statistical Analysis

- NED (1") and SRTM (1" research, 3" averaged and thinned)

- Divide US into 2.5' by 2.5' blocks (~500,000)

- Compute 35 parameters for each block

- Atlas of grids with results

- Graphs and tables to compare results

Single Area Analysis

- Show variability of computations

Atlas--35 Variables

Point and region variables

- Four distribution moments (average, standard deviation, skewness, kurtosis)
  - Elevation (z)
  - Slope in percent and degrees (dz)
  - Plan and profile curvature (d^2z)
- Gamma from variogram in four directions (sum squared elevation difference, divided by number of points and directional data spacing)
- Relief
- Roughness (Mark, 1975; Etzelmuller, 2000)
- Elevation relief ratio, or coefficient of dissection
- Terrain Organization (eigenvector analysis flatness, organization, direction)

Multiple measures of slope: Elev_Std, PlanC_Std, ProfC_Std, Relief, Rough_Fac, Slope°_Avg, Slope%_Avg, Slope%_Std, S1S2
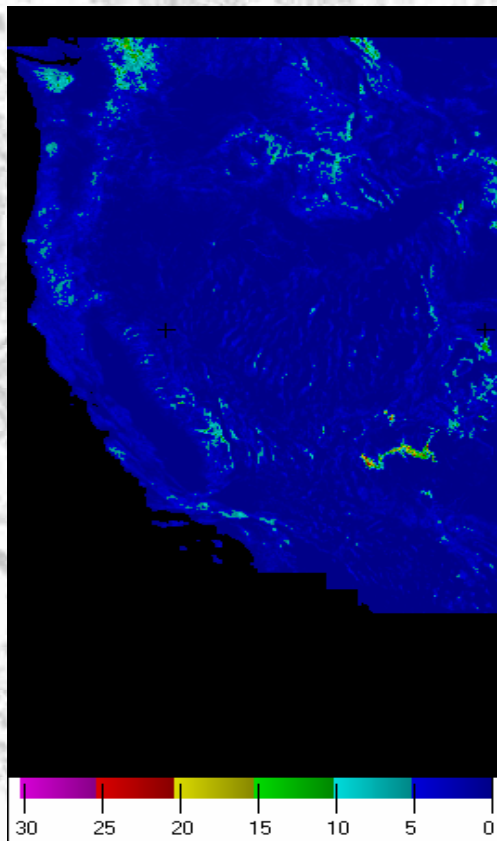
GAMMA_NS in meters for 1'' NED. Only the steepest parts of the American West stand out, especially the Grand Canyon and the North Cascades.
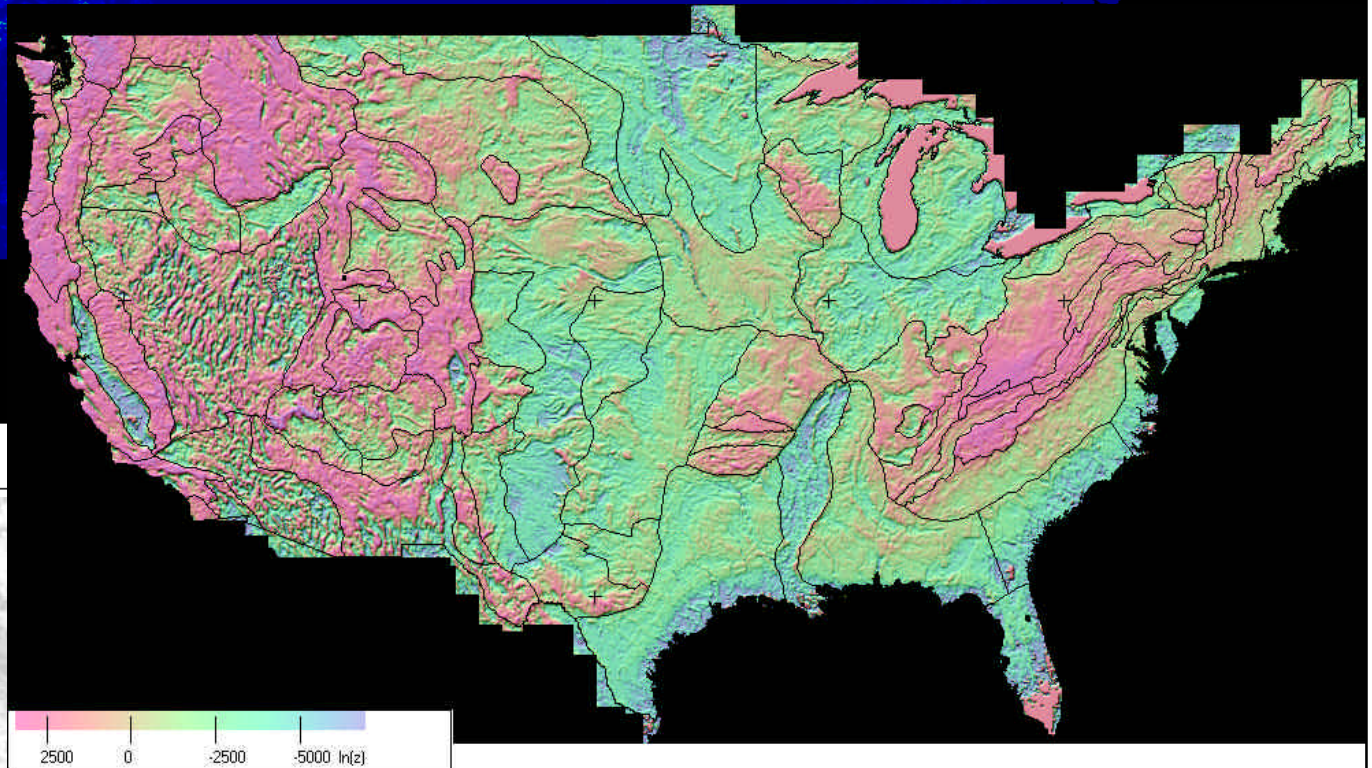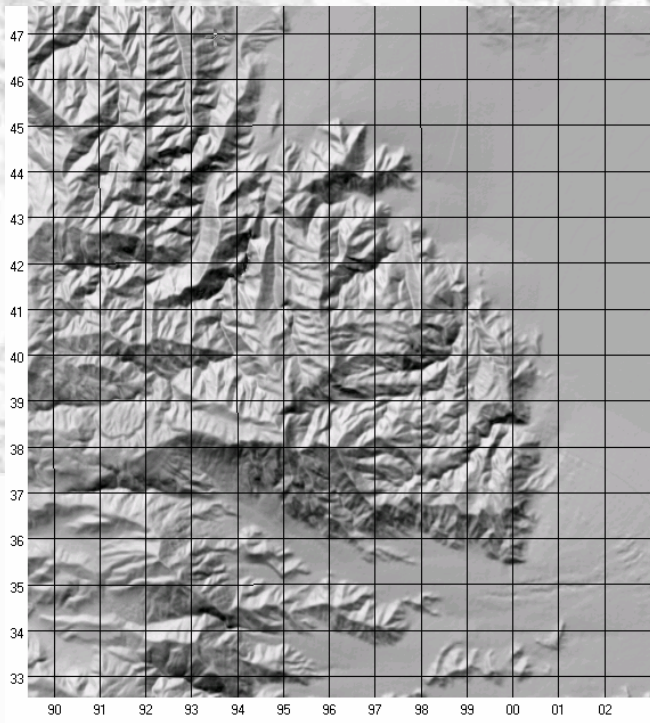
•**Logarithmic transformation applied to the GAMMA_NS data.**

•**Boundaries of Fenneman physiographic provinces shown.**

NED Terrain Organization
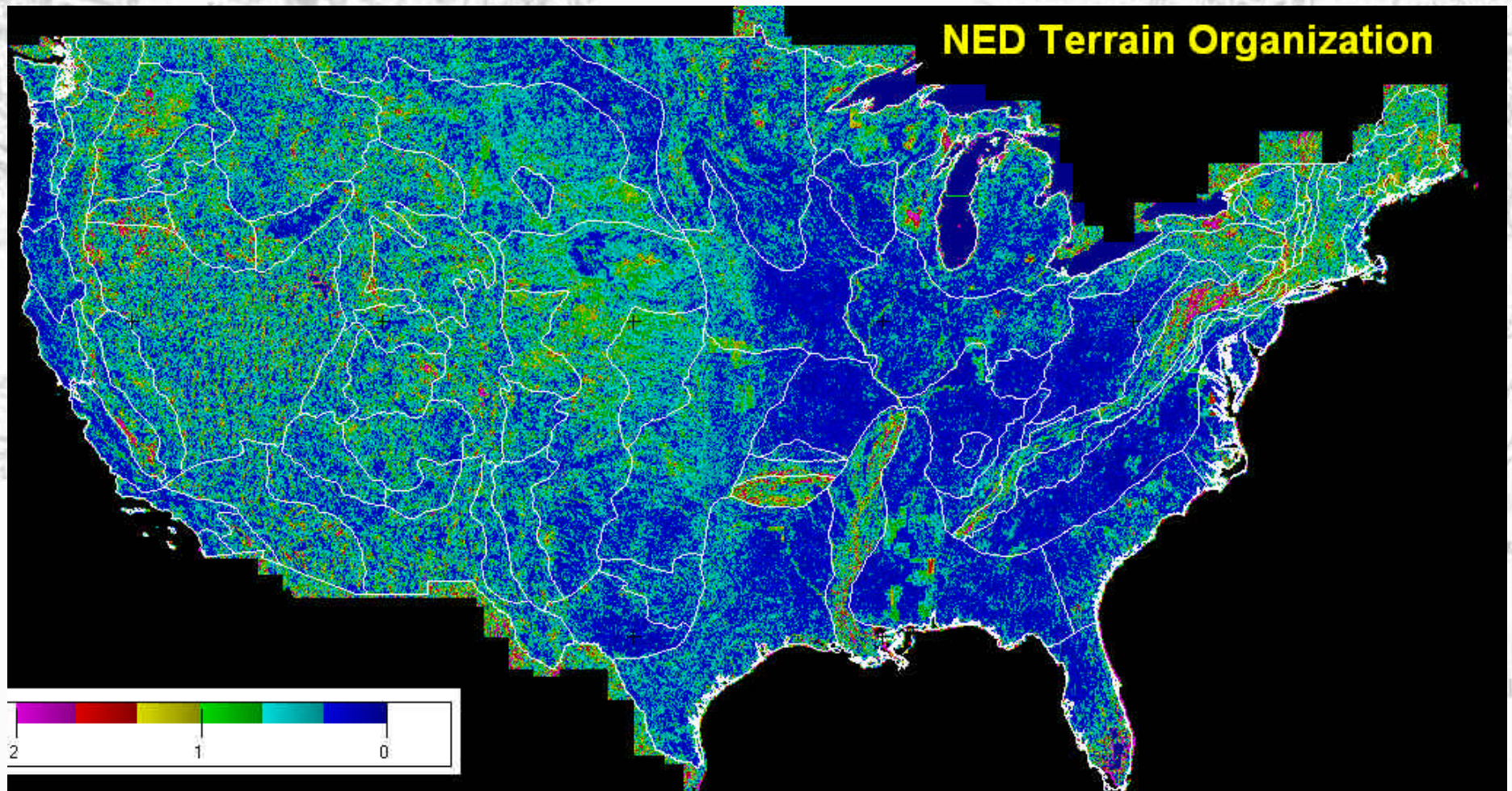
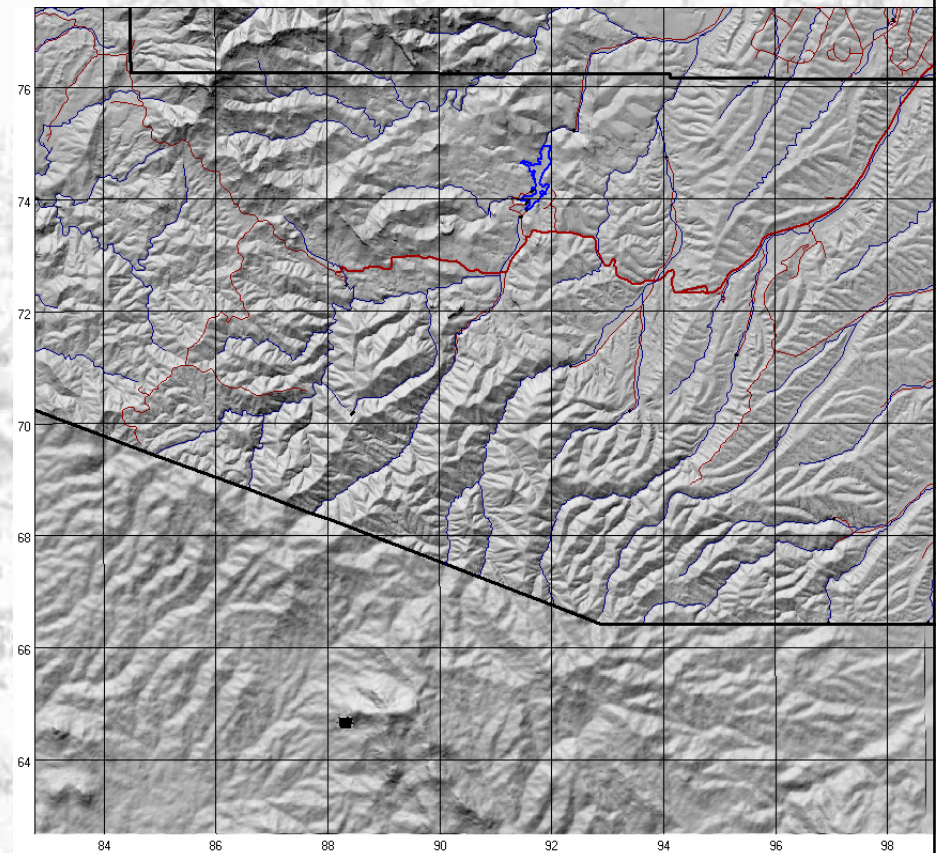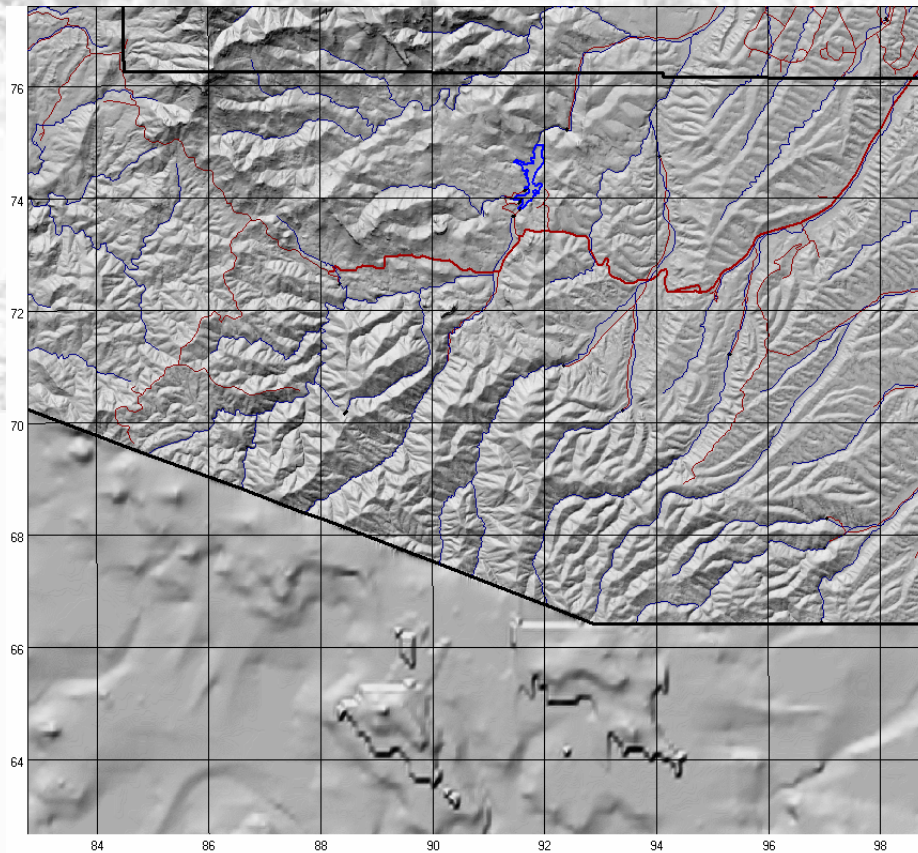Fenneman Provinces outlined in white

NED Issues

- •"Best available" DEM

- •Complete coverage downloaded summer of 2003
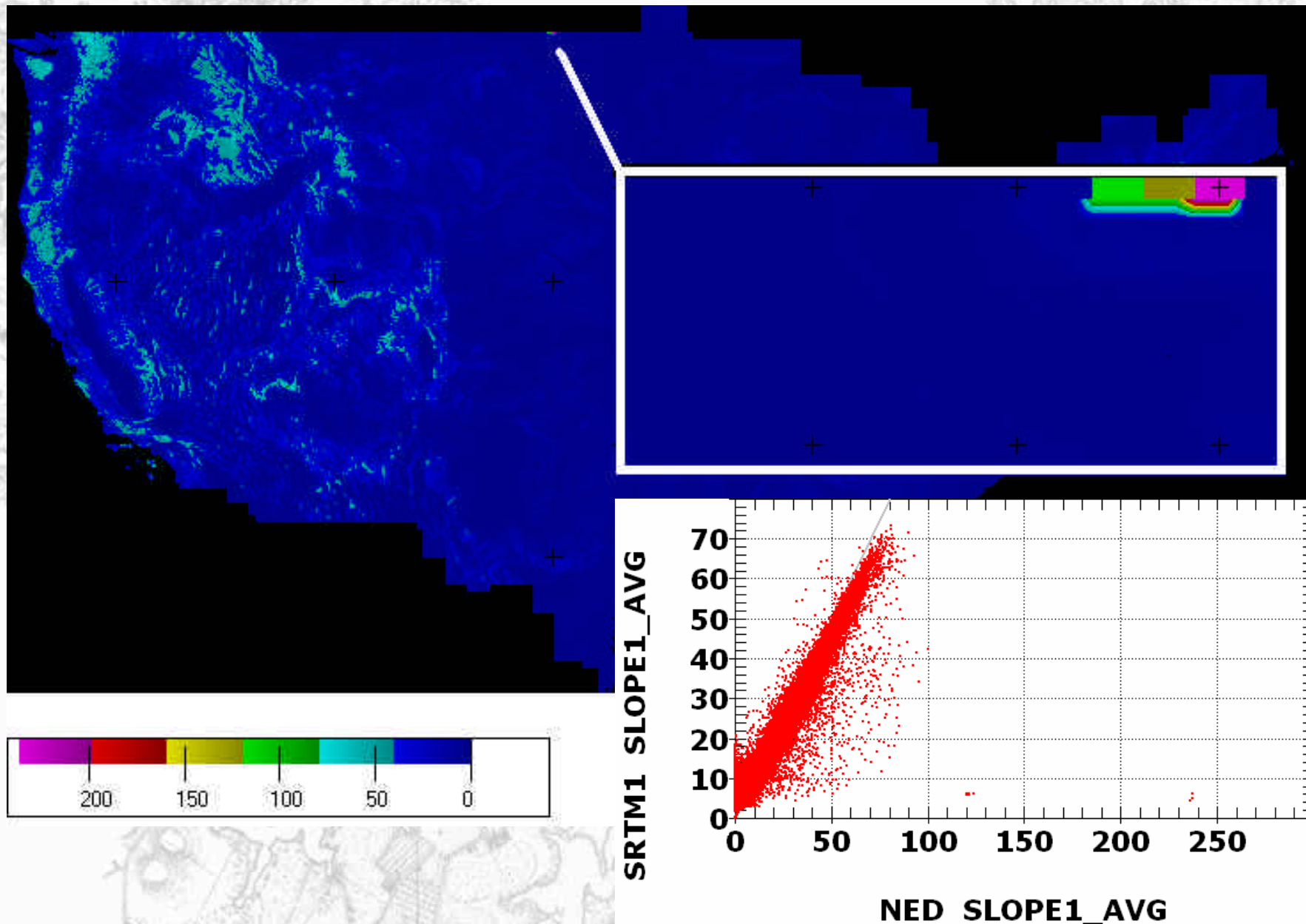
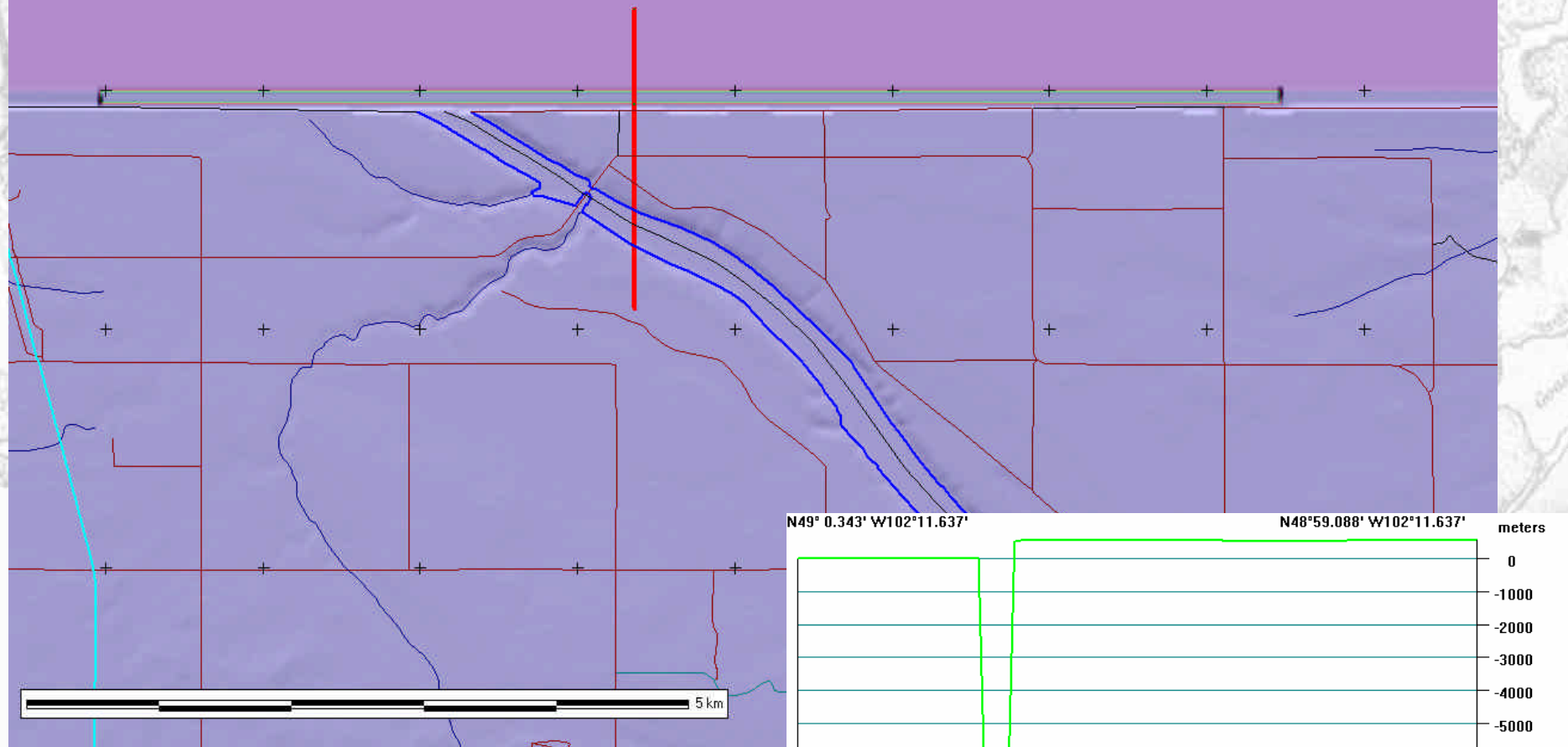- •Cross border "coverage" leads to suspect statistics

NED

Uses 1:250K DEM in Mexico   Could use SRTM-1" in Mexico

NED Average Slopes

Great Homeland Security Ditch

N49° 0.343' W102°11.637'   N48°59.088' W102°11.637'   meters

NED along the Canadian Border, W102

•Canada set to 0

•Missing data along border set to –9998 and –10000 rather than -9999

SRTM

Used for statistics

• Research grade, 1" and 3", from USGS/NASA ftp sites (currently ftp://e0mss21u.ecs.nasa.gov/srtm/)

• 3" thinned from 1"

Consulted but not used

• Final, SDDS—holes at sea level (http://seamless.usgs.gov/) in some of the available formats (i.e. BIL)

• SRTM DTED2—water corrections have minimal impact on statistics

SRTM Issues

•**Final SRTM has some holes set to sea level with valid sea level elevations also present in DEM (SDDS downloads, June 2005, BIL format)**

•**Holes will affect statistics since they tend to be in steeper terrain**

•**SRTM research data has noisy ocean data along coasts and other problems with water**
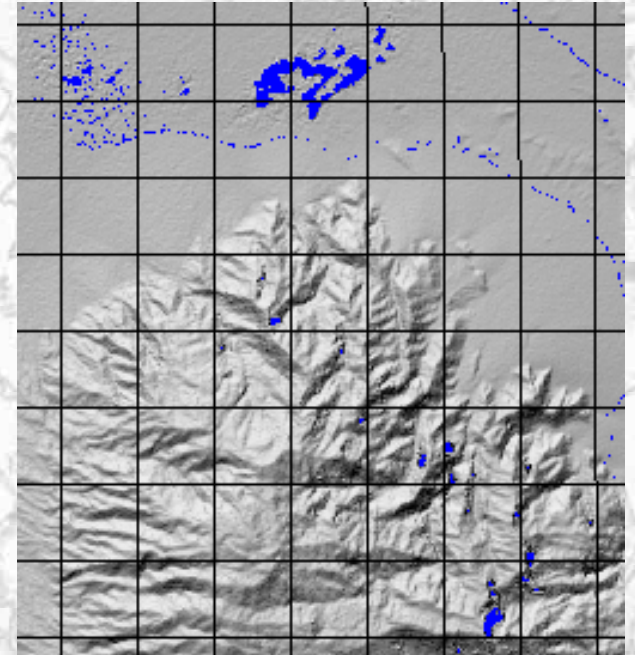
Orbital Patterns on SRTM Atlas Files
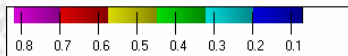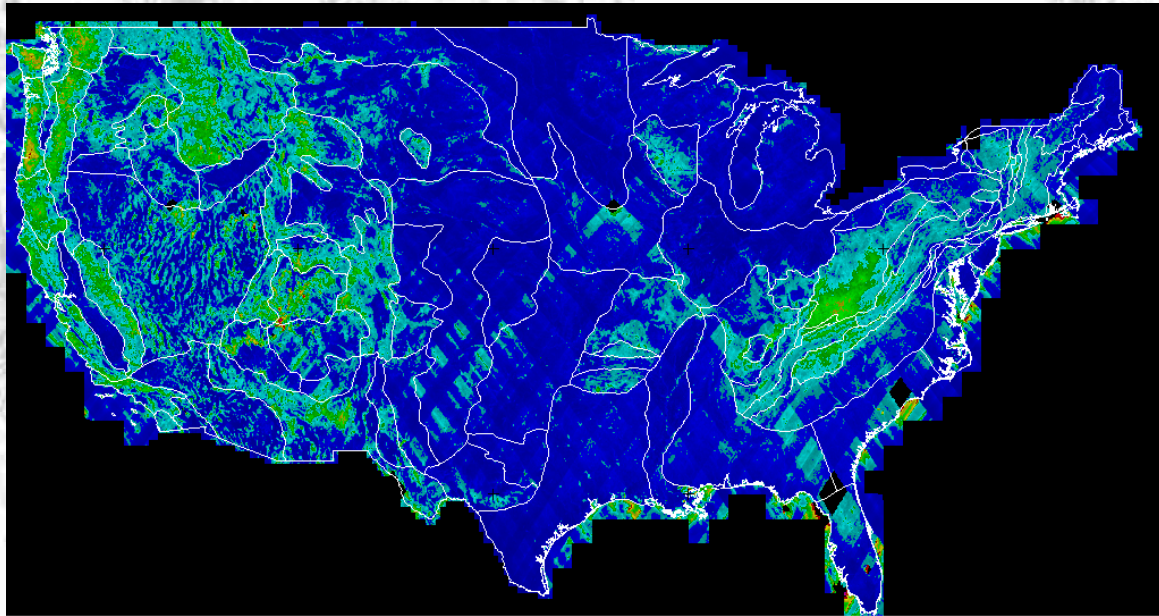
Profile Curvature Standard Deviation

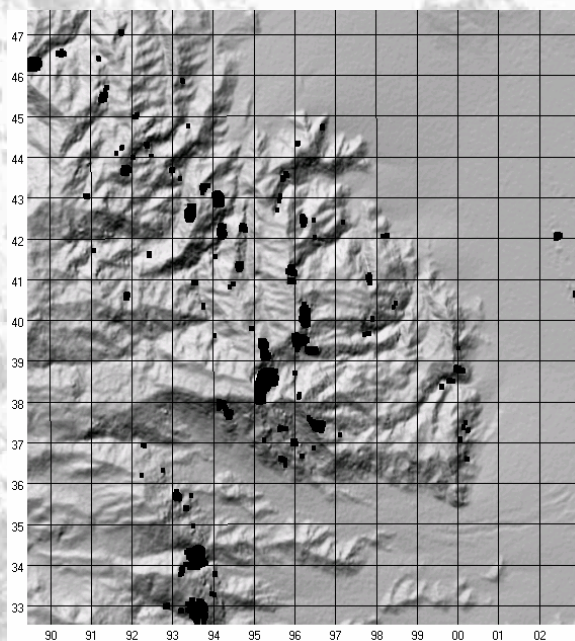**S2S3, Terrain Organization Parameter**
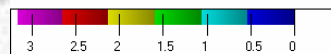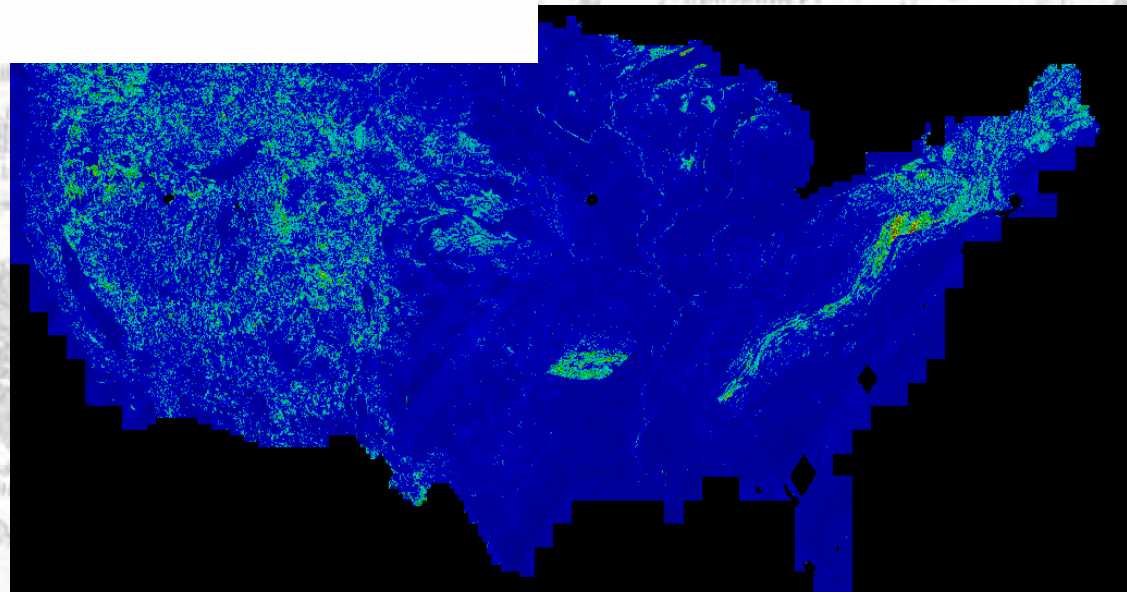
NED Profile Curvature Std Dev

NED Profile Curv Std
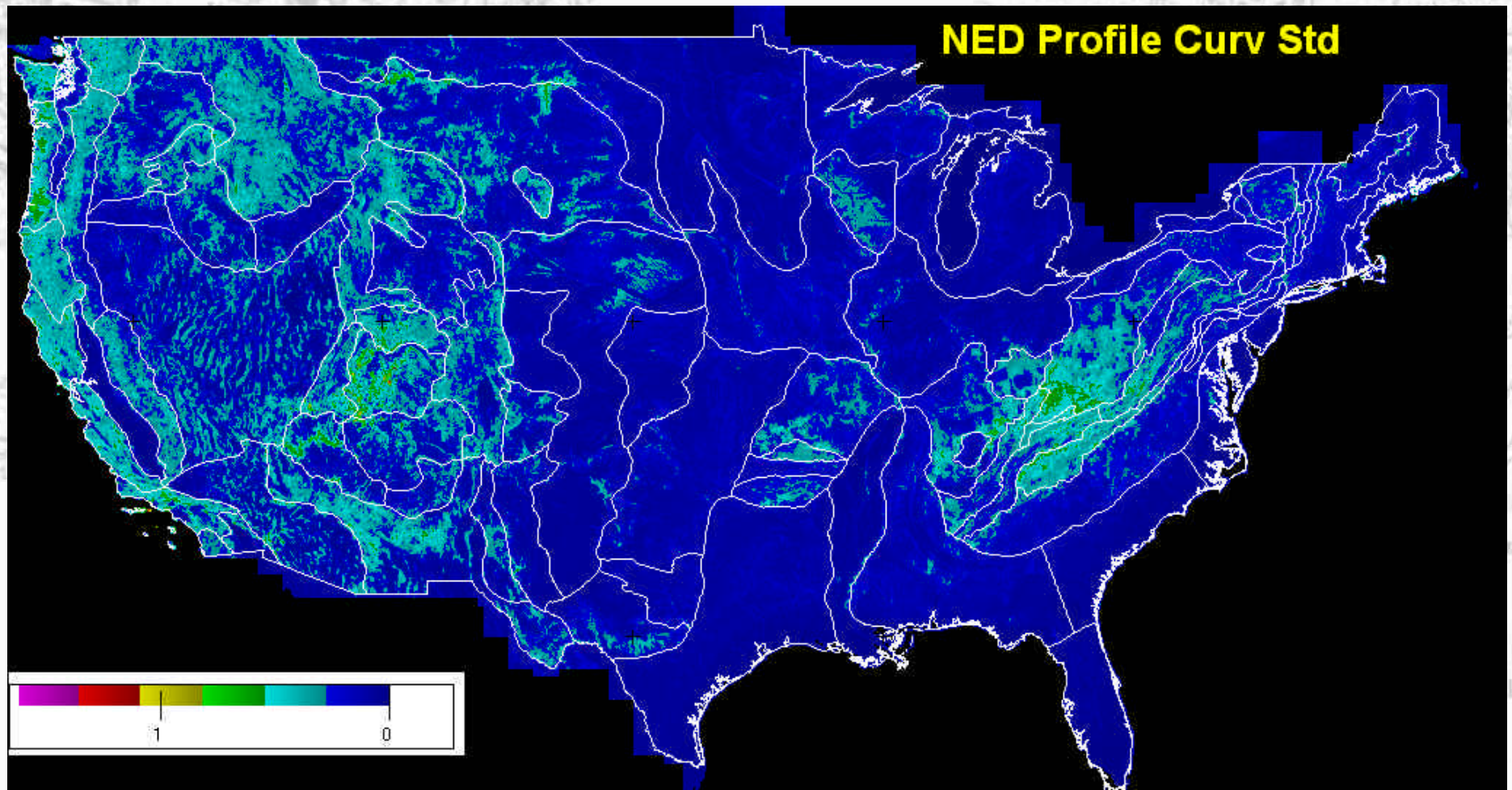
Fenneman Provinces outlined in white

SRTM Visual Test— Death Valley
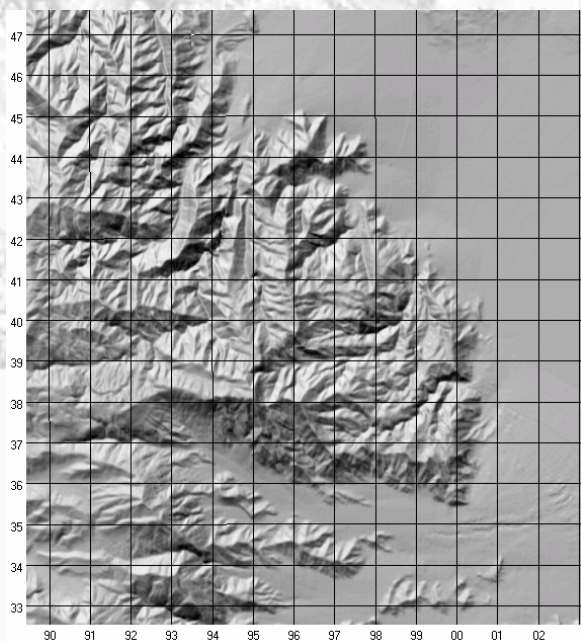
NED

SRTM Research
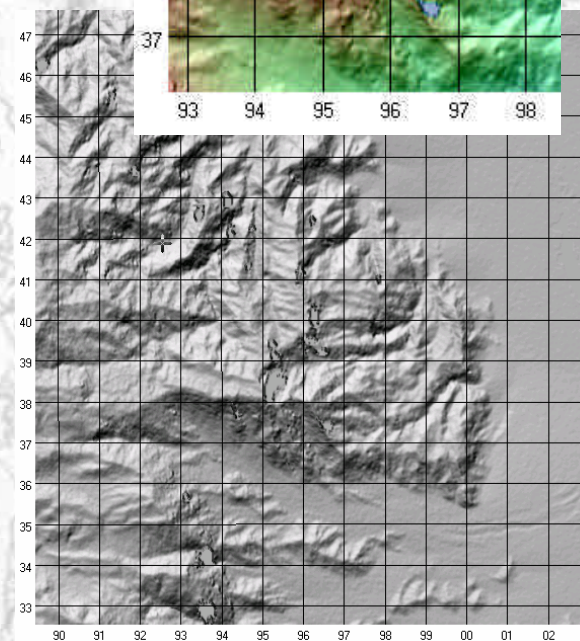
SRTM Final

(SDDS, holes set to sea level)
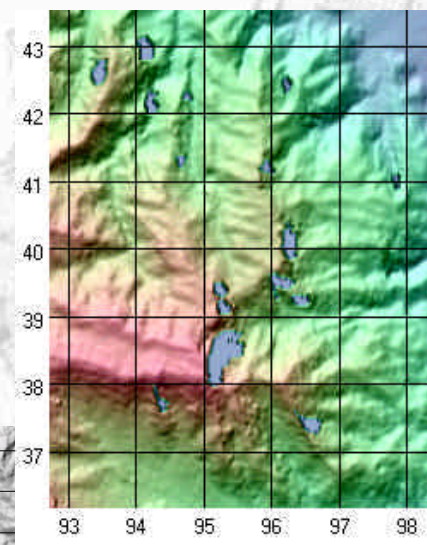
SRTM Research Compared to NED—Good News

NED ELEV_STD / SRTM ELEV_STD

PARAMETER	NED SRTM1-res	NED SRTM3-THIN	NED SRTM3-AVG
ELEV_AVG	0.999909	0.999925	0.999928
RELIEF	0.994462	0.995533	0.995621
ELEV_STD	0.988805	0.989480	0.989760
ROUGH_FAC	0.973240	0.949702	0.946258
SLOPE°_AVG	0.971683	0.967254	0.964338
SLOPE%_AVG	0.967332	0.961725	0.959396
SLOPE°_STD	0.943543	0.937880	0.935393
SLOPE%_STD	0.928674	0.913974	0.915190
GAMMA_NWSE	0.910758	0.891161	0.887920
GAMMA_NESW	0.906297	0.888306	0.884645
GAMMA_NS	0.901991	0.888594	0.881760
PLANC_STD	0.874393	0.833612	0.831960
GAMMA_EW	0.873012	0.863762	0.858427
MAX_SLOPE	0.826260	0.881000	0.881310
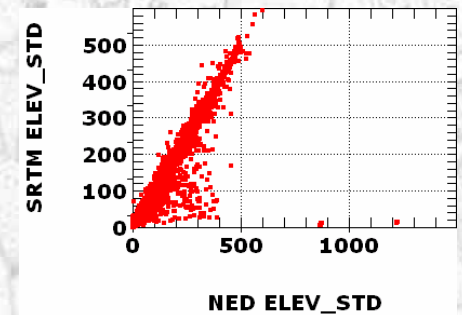
Near perfect to very good agreement:

•**Elevation mean and standard deviation**

•**Slope mean and standard deviation, degrees or percent**

•**Gamma**

•**Relief**

•**Roughness factor**

•**Standard deviation of plan curvatures**

•**Maximum slope**

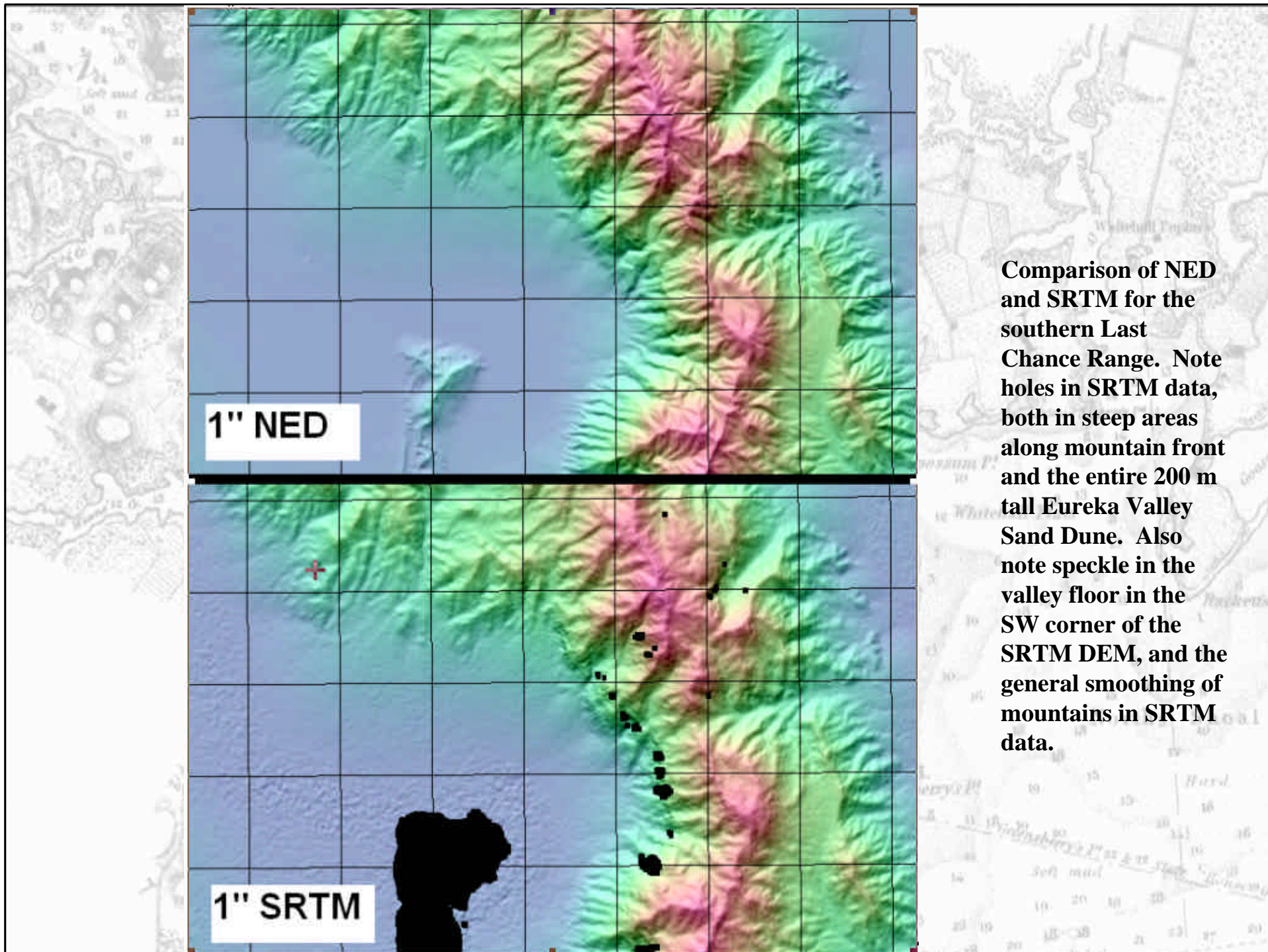
NED MAX_SLOPE / SRTM MAX_SLOPE
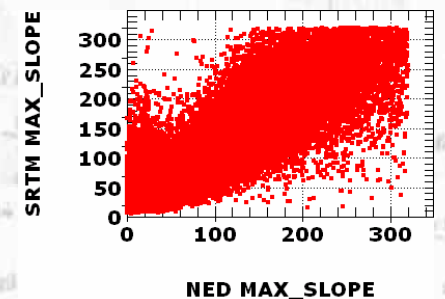
NED to SRTM
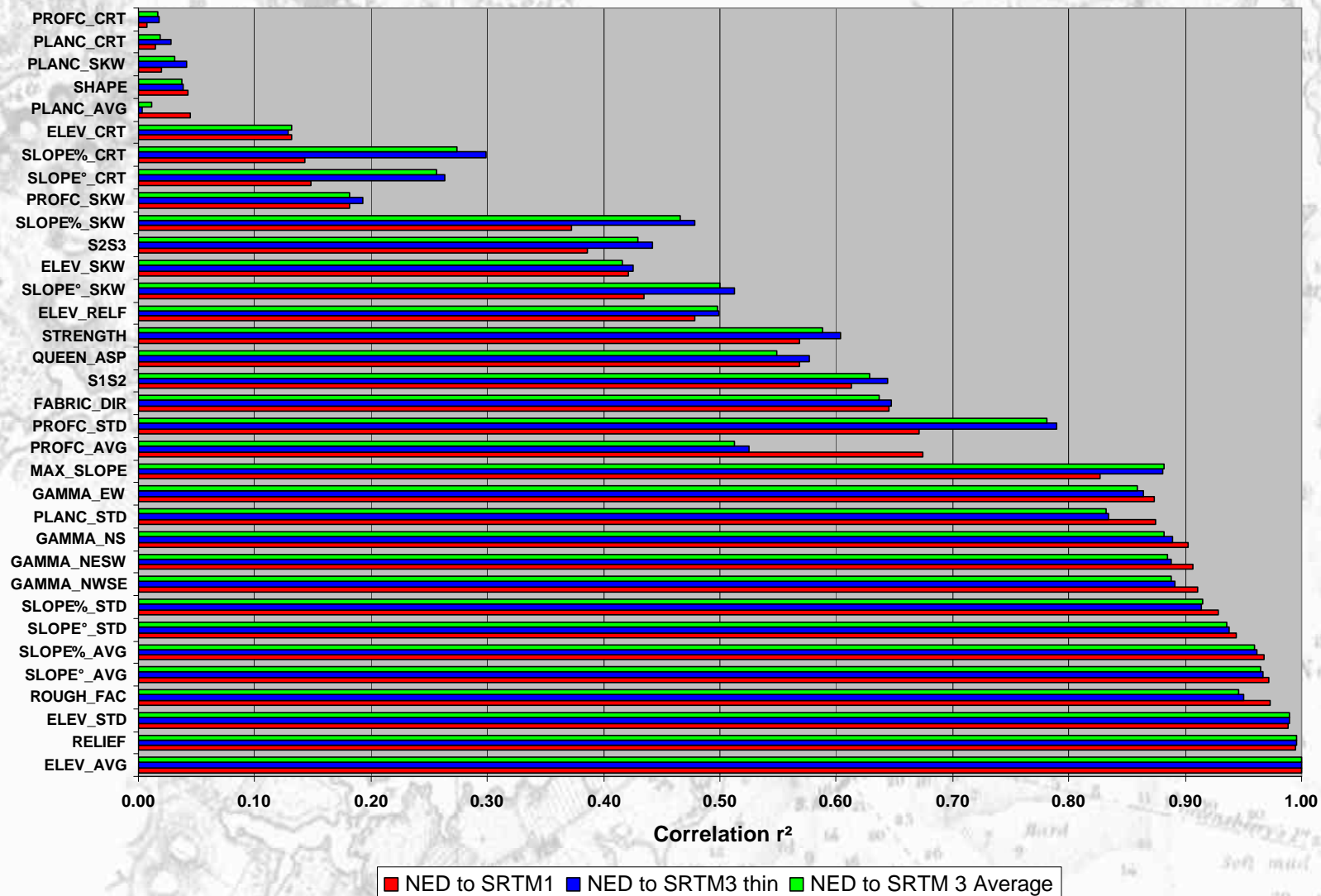
SRTM Research 1" versus 3"
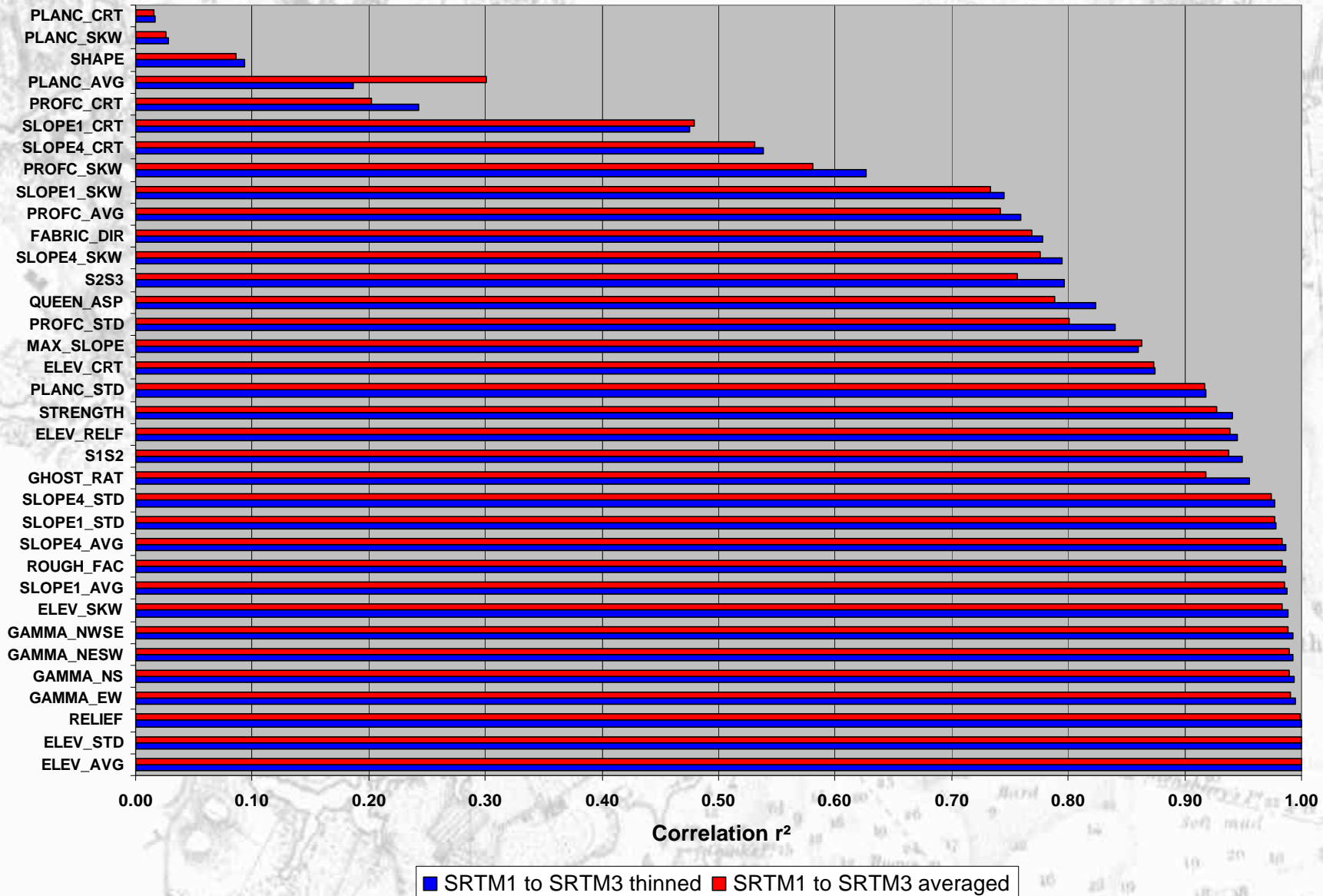
Thinning versus Averaging for SRTM 3"

1" NED

1" SRTM
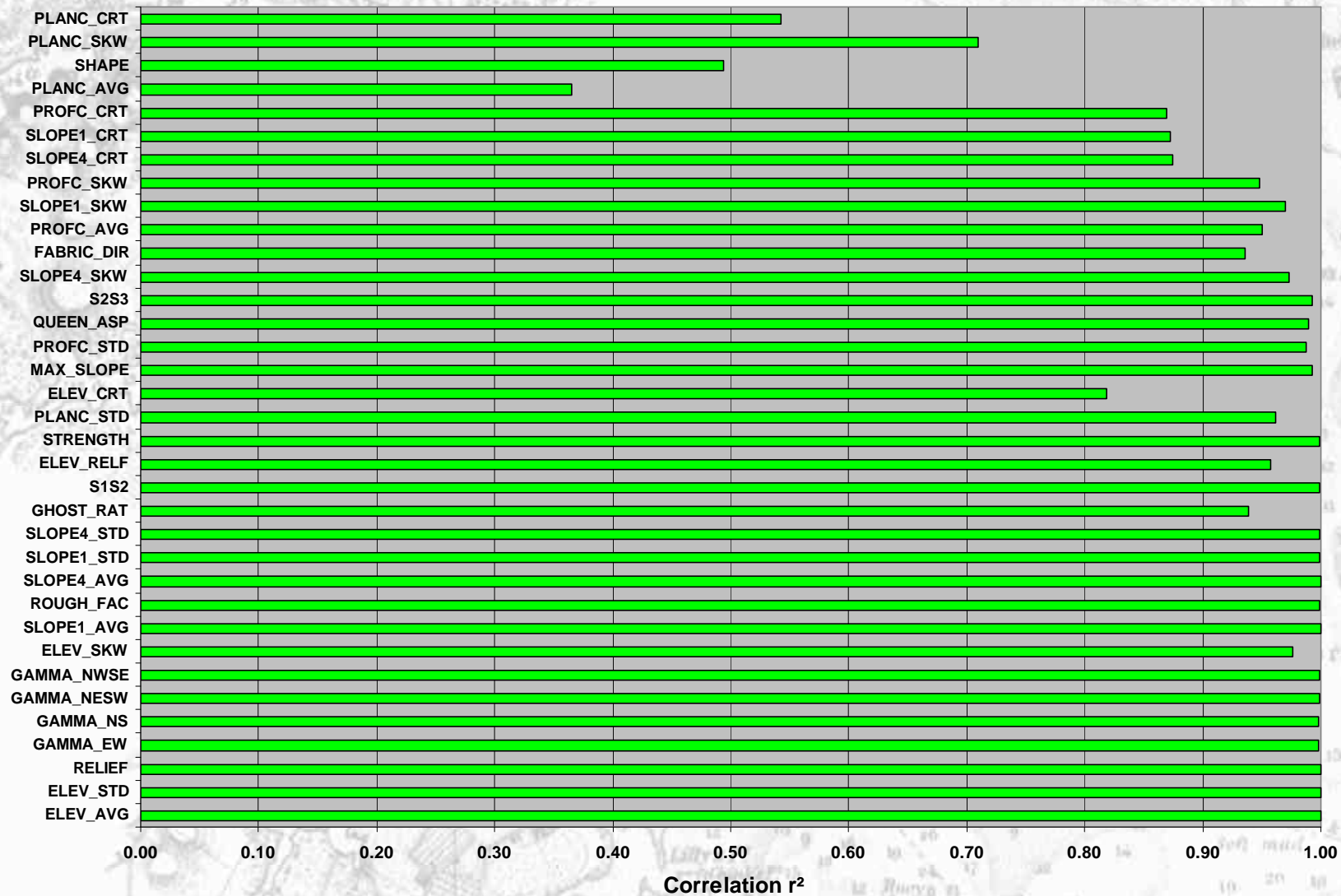
Comparison of NED and SRTM for the southern Last Chance Range. Note holes in SRTM data, both in steep areas along mountain front and the entire 200 m tall Eureka Valley Sand Dune. Also note speckle in the valley floor in the SW corner of the SRTM DEM, and the general smoothing of mountains in SRTM data.
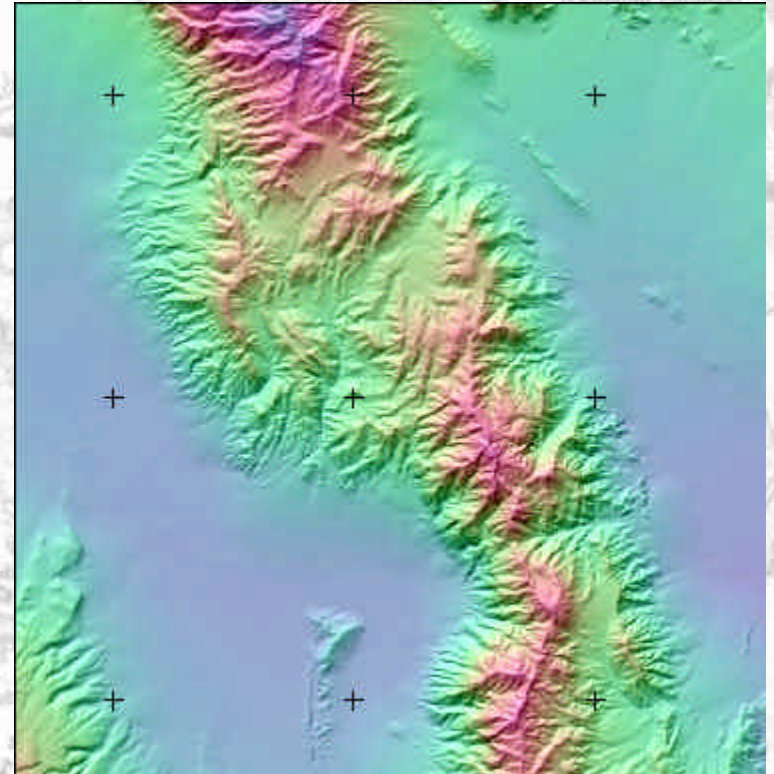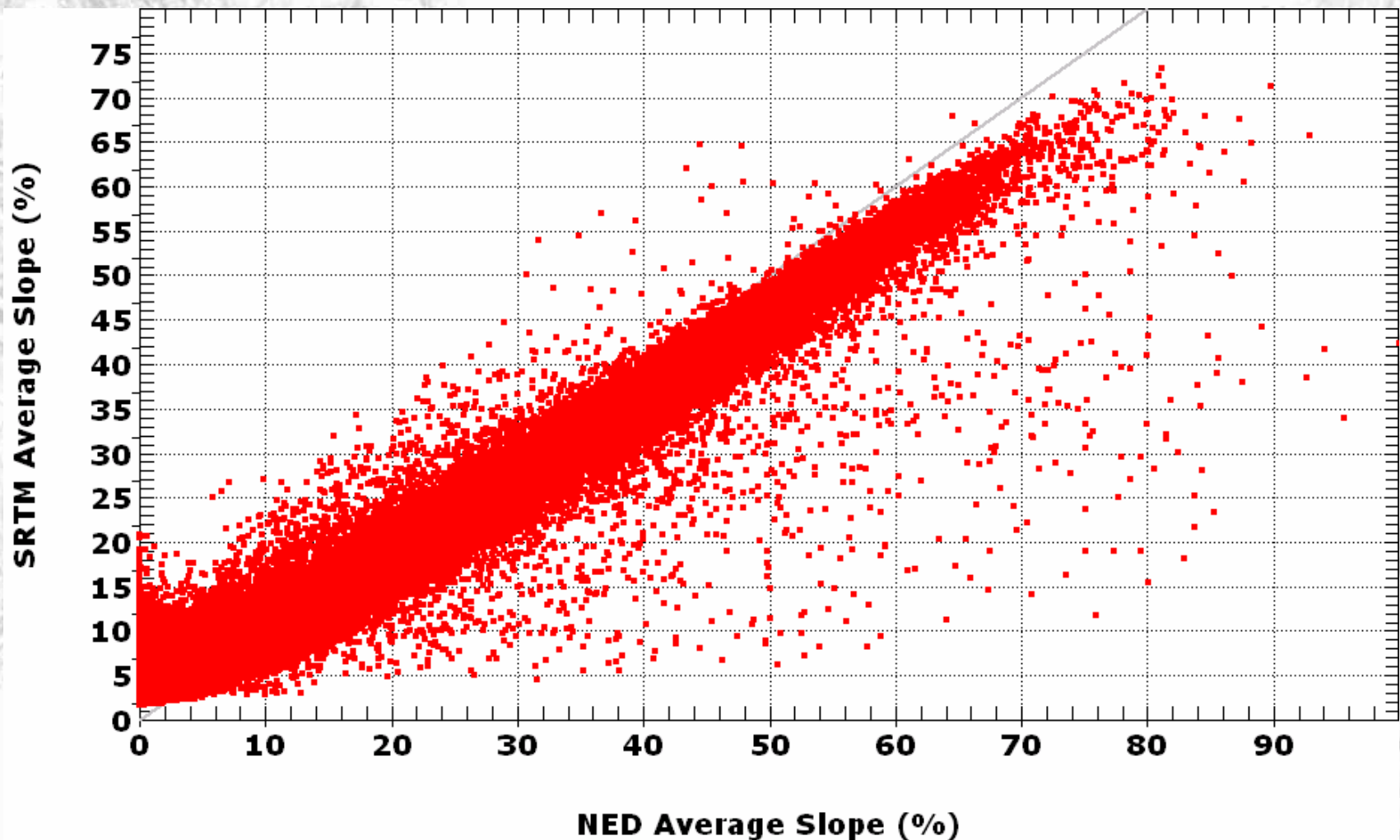
Last Chance Range Slopes
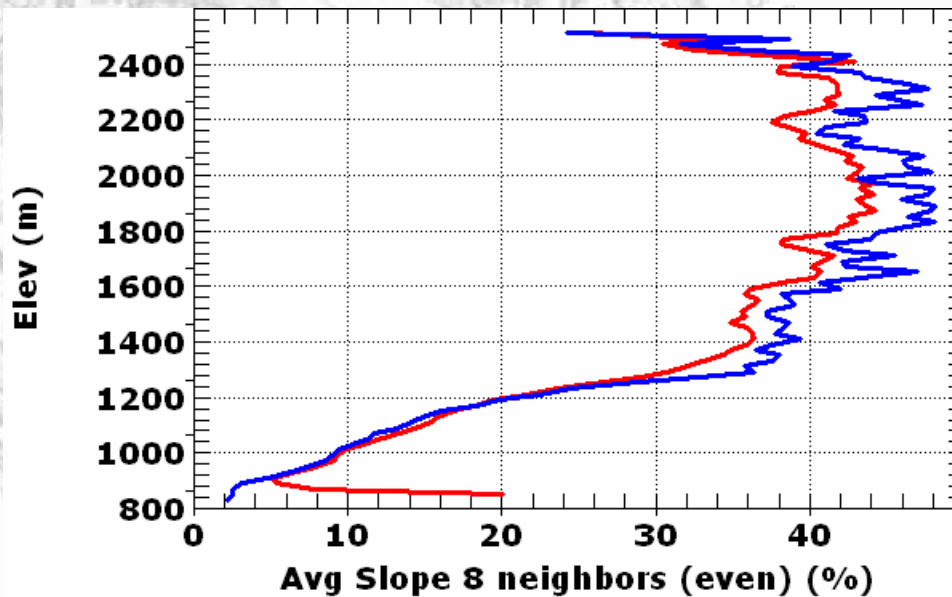
SRTM
NED

- SRTM slopes excessive in playa
- NED steeper in mountains

US Averages

• 500,000 points; outliers emphasized visually

• SRTM too steep for gentle topography (radar speckle; min 2% average slope)

• SRTM not steep enough for mountains (smoothing)

NED Average Slope Compared to SRTM from Atlas
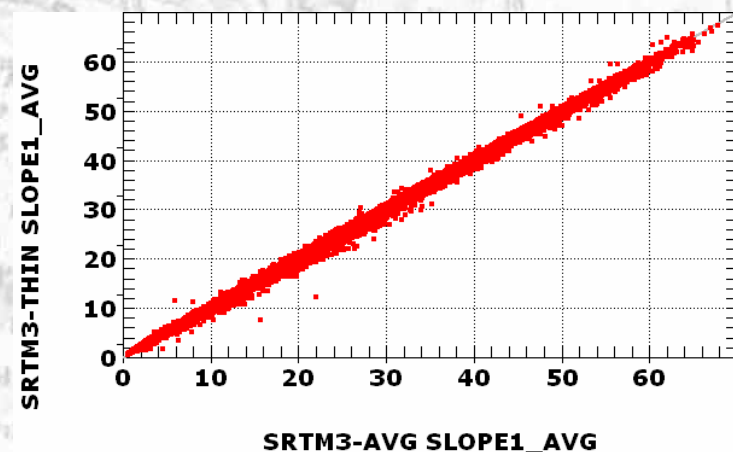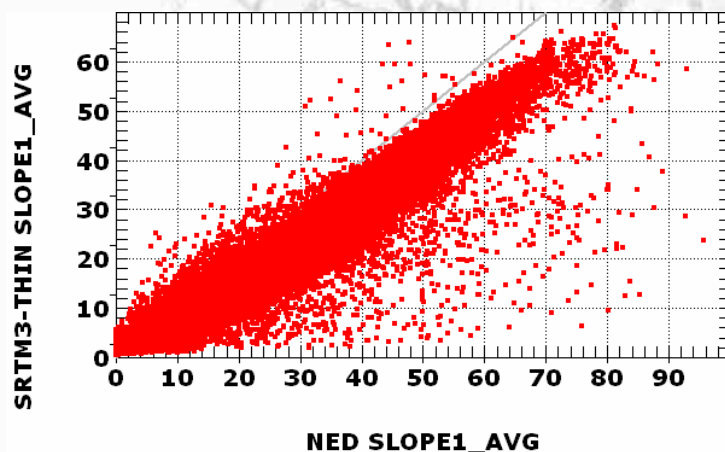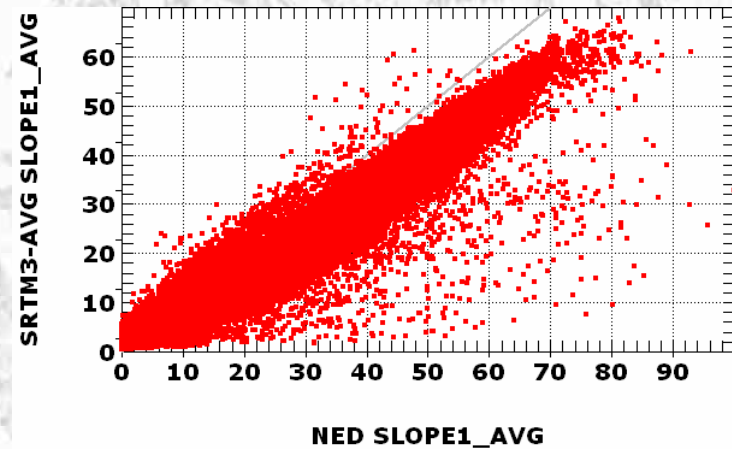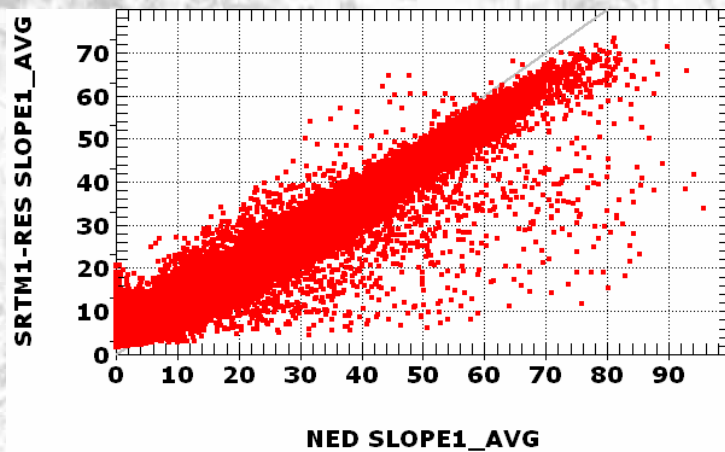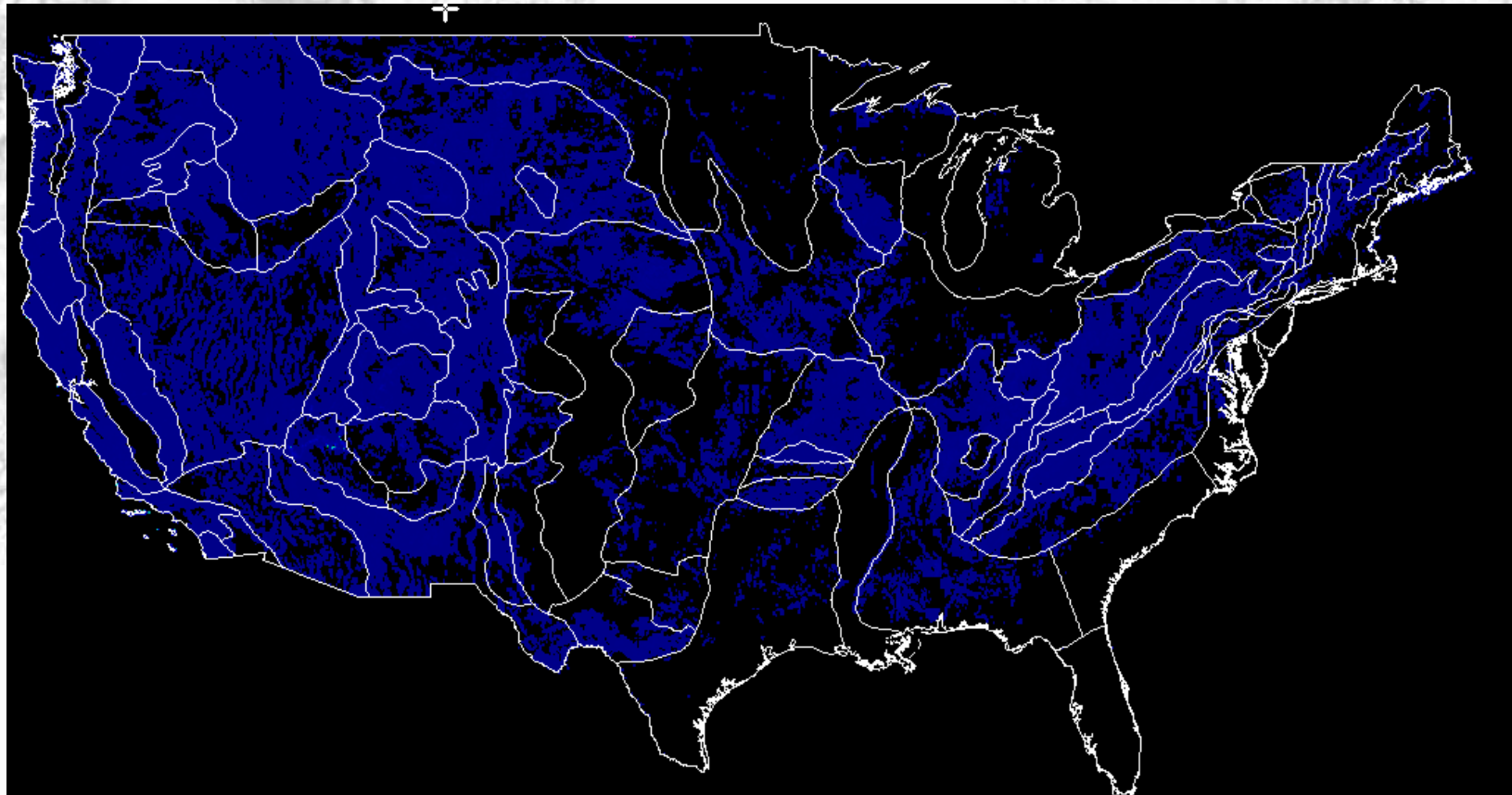
Average Slope, SRTM 1" > NED
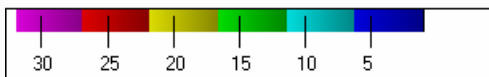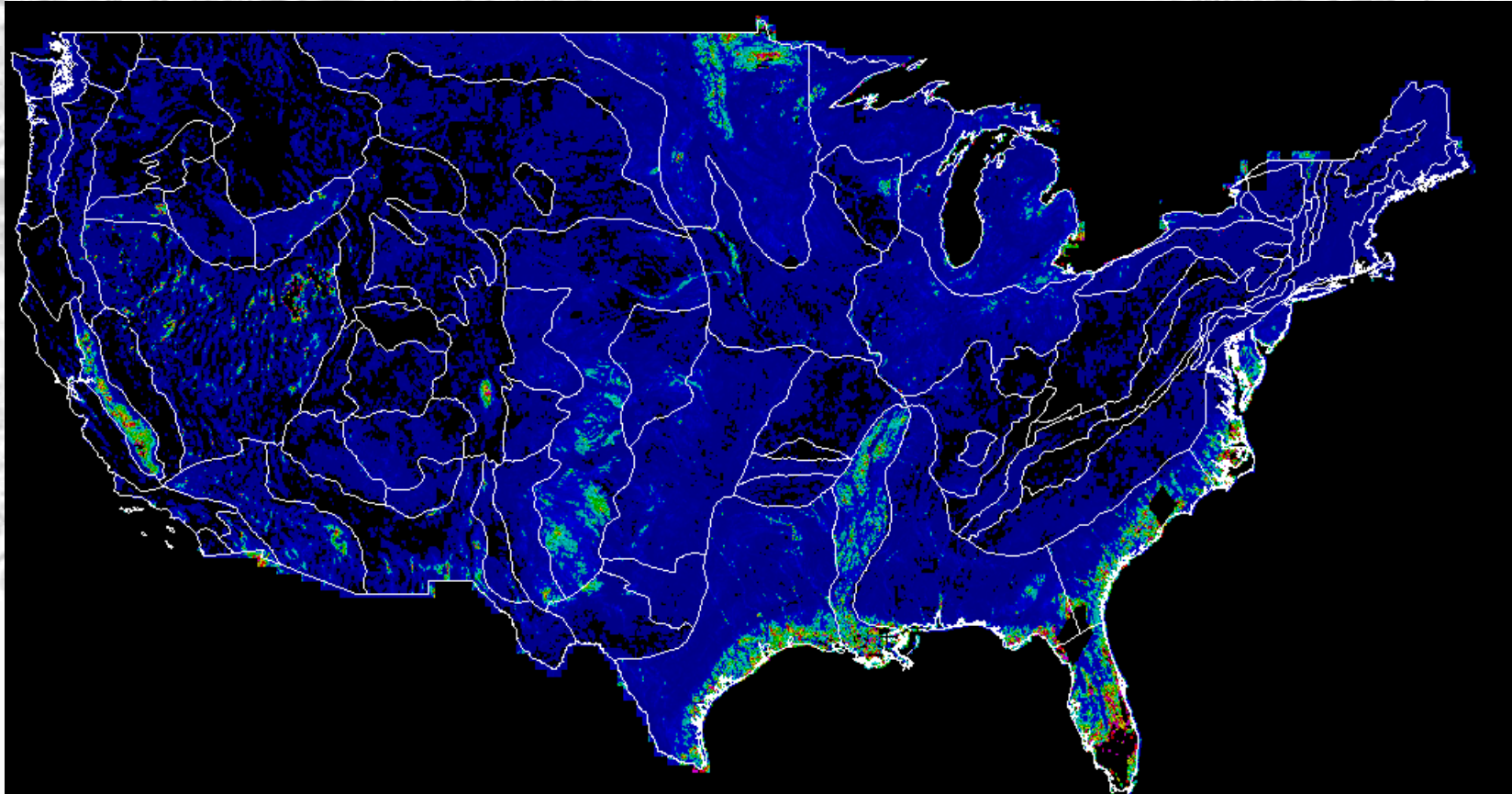
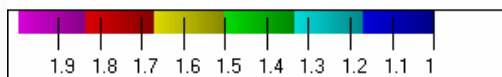Great Valley
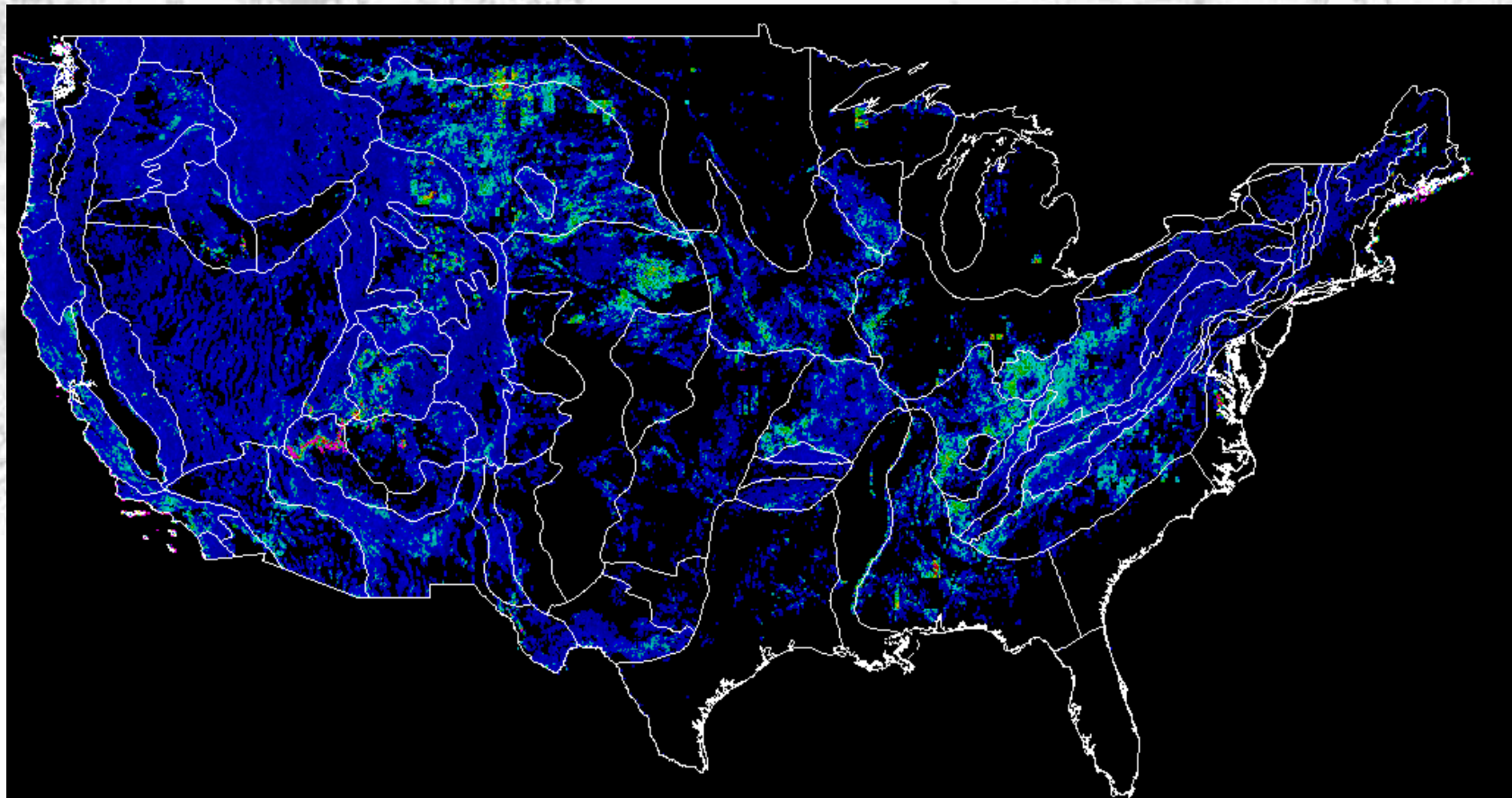
Atlantic Coastal Plain

Interior Plains

Valleys in Great Basin

Average Slope, NED > SRTM 1"
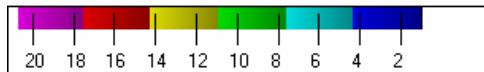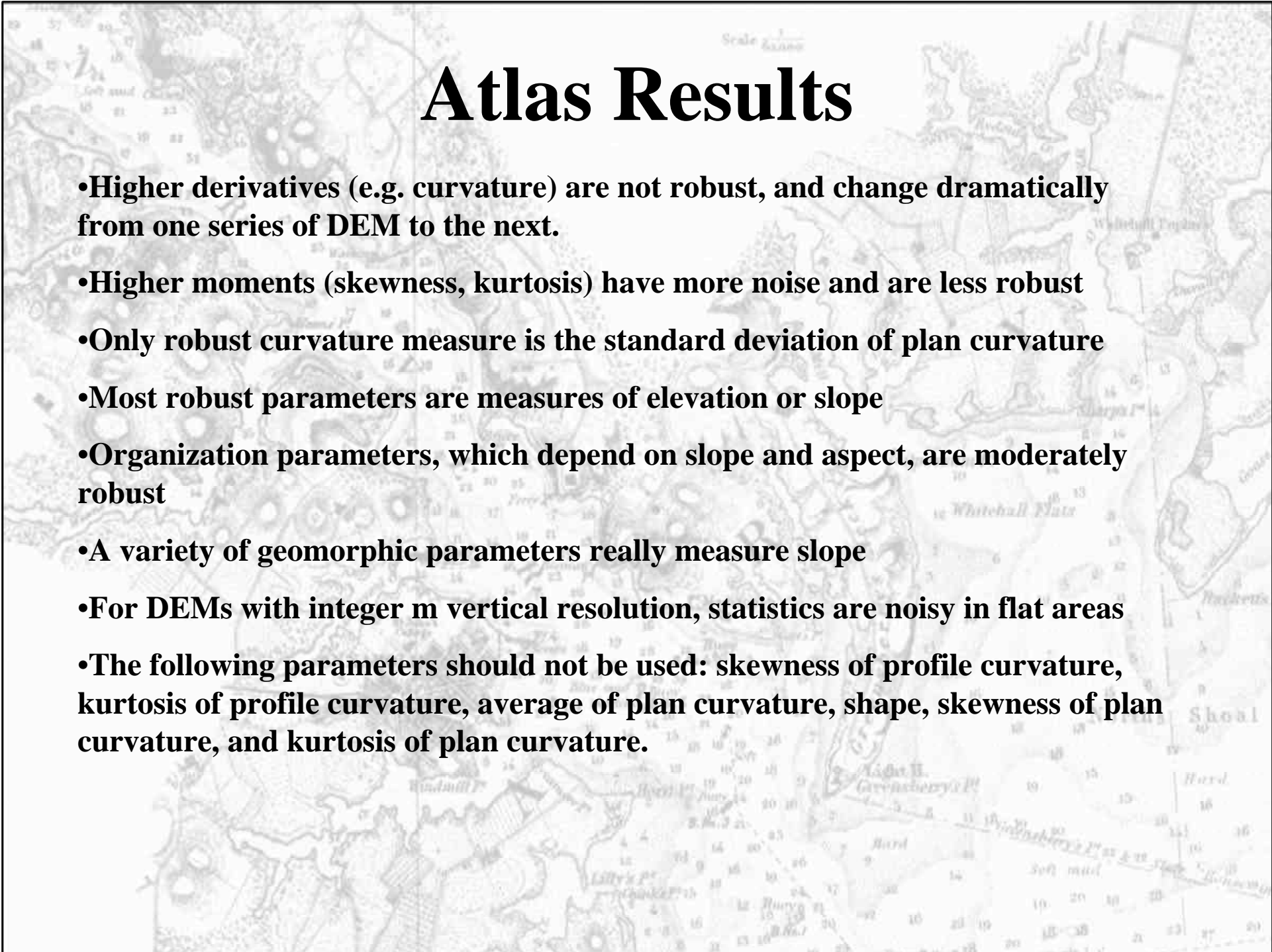
Very few large values (along coasts and Canadian Border)

Average Slope, NED > SRTM 1"

| 1.9 | 1.8 | 1.7 | 1.6 | 1.5 | 1.4 | 1.3 | 1.2 | 1.1 | 1 |

Moderate values in Grand Canyon, Mountainous West

Smoothing and holes both contribute

Atlas Results

- Higher derivatives (e.g. curvature) are not robust, and change dramatically from one series of DEM to the next.

- Higher moments (skewness, kurtosis) have more noise and are less robust

- Only robust curvature measure is the standard deviation of plan curvature

- Most robust parameters are measures of elevation or slope

- Organization parameters, which depend on slope and aspect, are moderately robust

- A variety of geomorphic parameters really measure slope

- For DEMs with integer m vertical resolution, statistics are noisy in flat areas

- The following parameters should not be used: skewness of profile curvature, kurtosis of profile curvature, average of plan curvature, shape, skewness of plan curvature, and kurtosis of plan curvature.
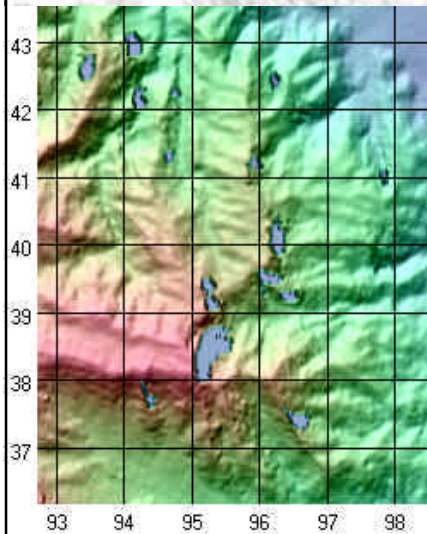
Slope Distribution by Elevation
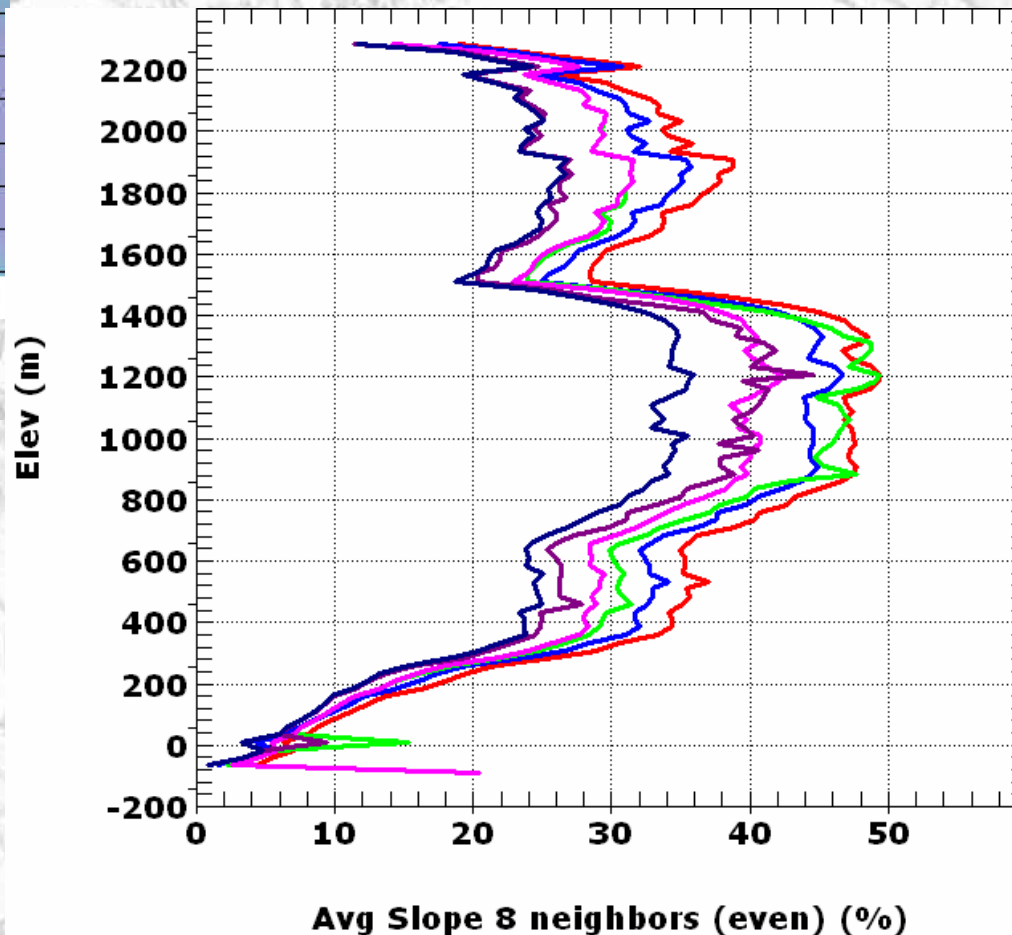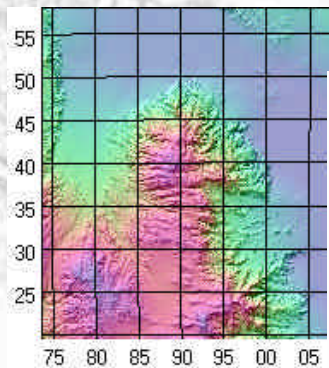
NED_THIRD
NED_ONE
SRTM_ONE
SRTM_RES_ONE
SRTM_THREE
SRTM_RES_THREE

- 1/3" steepest
- 3" gentlest
- 3" Research gentler because of averaging
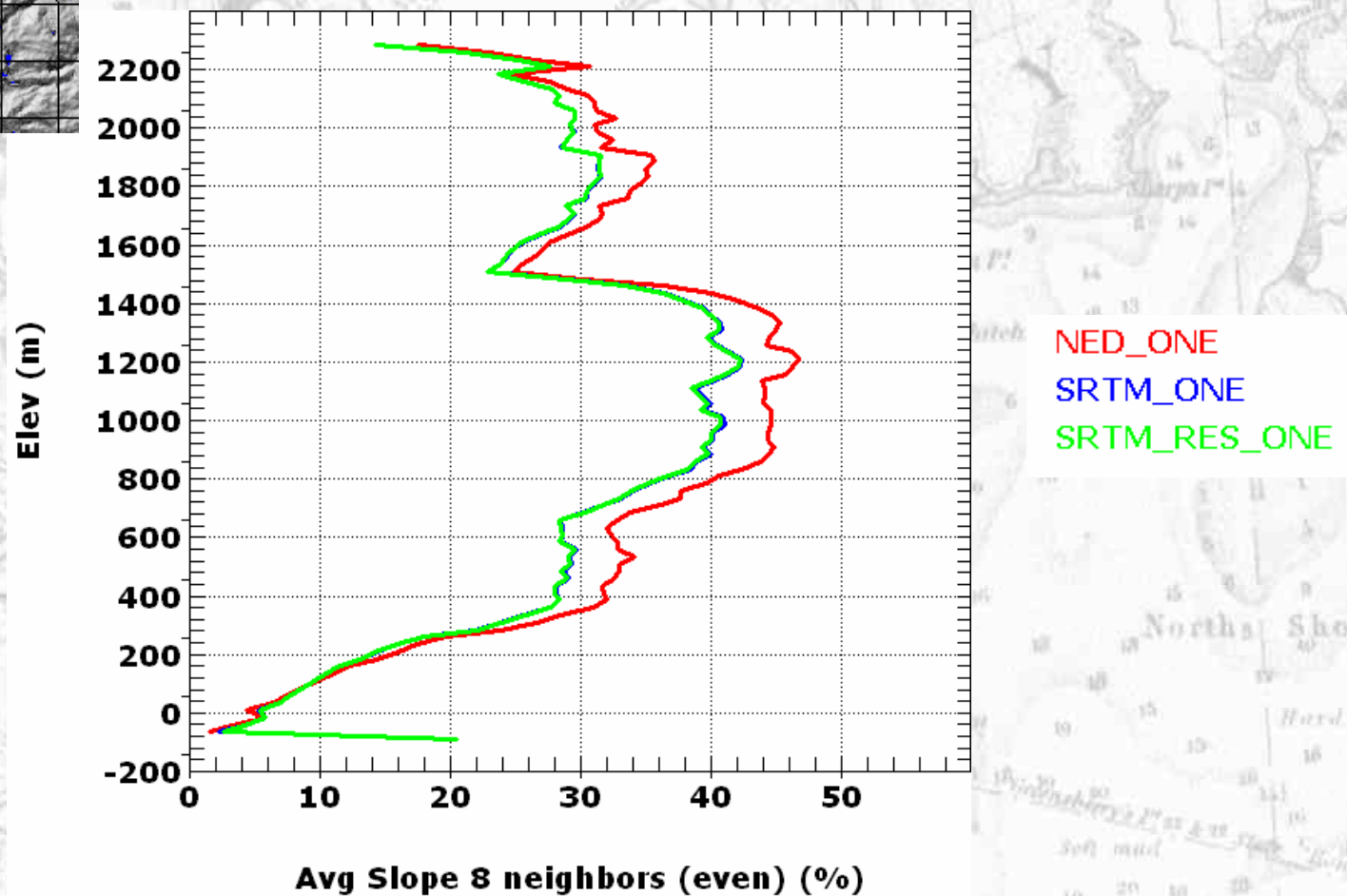- Differences vary by elevation

Death Valley, Tucki Mtn

Zero Elevations Skew SRTM Final

NED_ONE
SRTM_ONE
SRTM_RES_ONE

- Along holes, go from 0 to 1200 m for some pretty steep values

- Get steep slopes at 0 elevation and at 800-1400

Death Valley, Tucki Mtn

Make Sea Level Missing,
SRTM Final ≈ SRTM Research

Death Valley, Tucki Mtn

Plan Curvature

Plan Curvature Statistic	NED	SRTM
Mean	–0.00	–0.00
Average deviation	0.04	0.03
Standard deviation	0.08	0.07
Skewness	0.7216	–0.1150
Kurtosis	31.1539	77.8054

NED
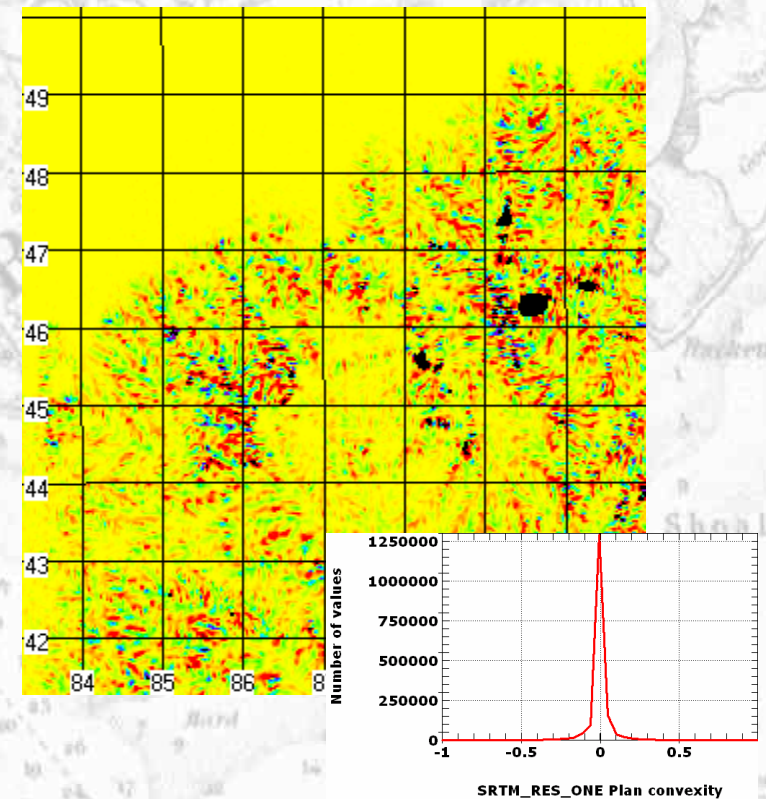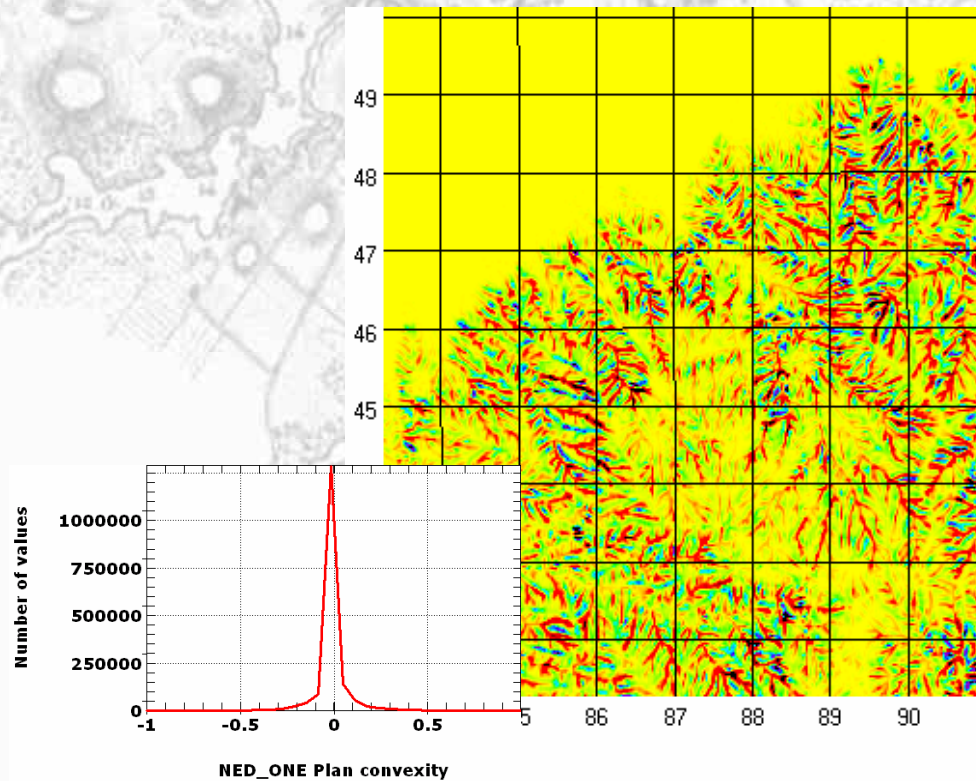
SRTM

Upward Openness

Openness Statistic	NED	SRTM
Mean	84.22	84.55
Average deviation	5.12	4.31
Standard deviation	6.29	5.43
Skewness	-1.2272	-1.3811
Kurtosis	1.1890	2.0233

NED_ONE Openness (+ upward, L=1000)

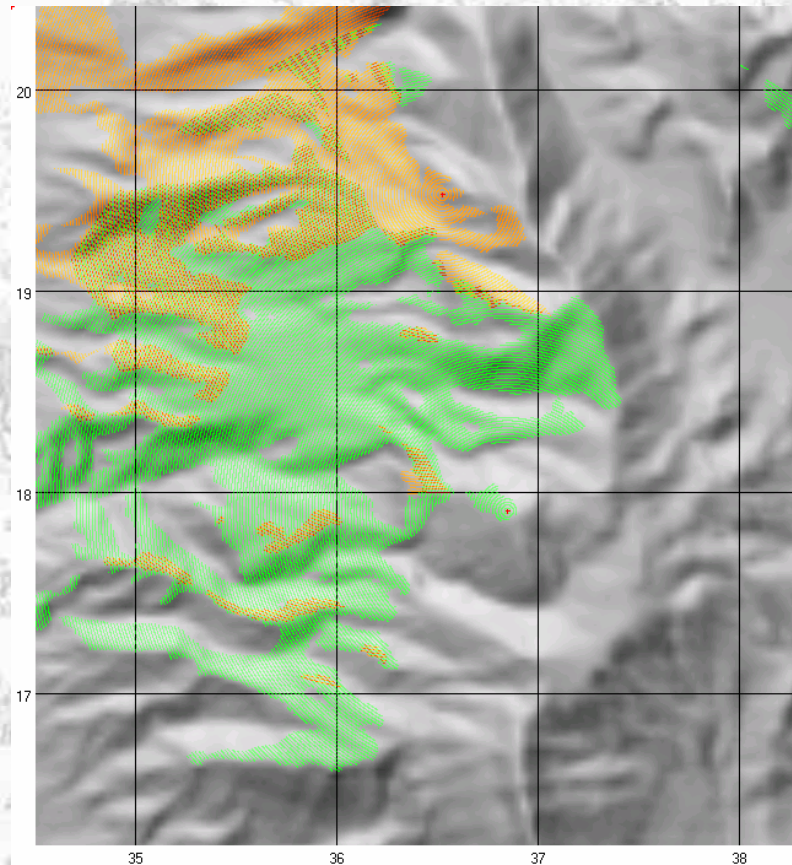SRTM_RES_ONE Openness (+ upward, L=1000)
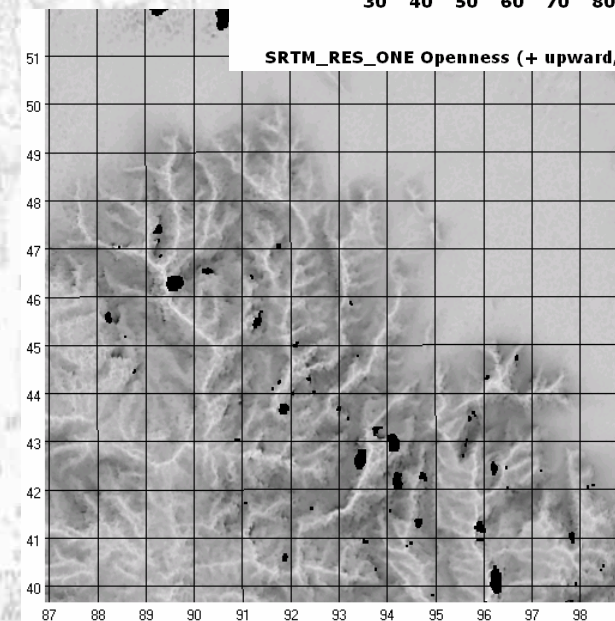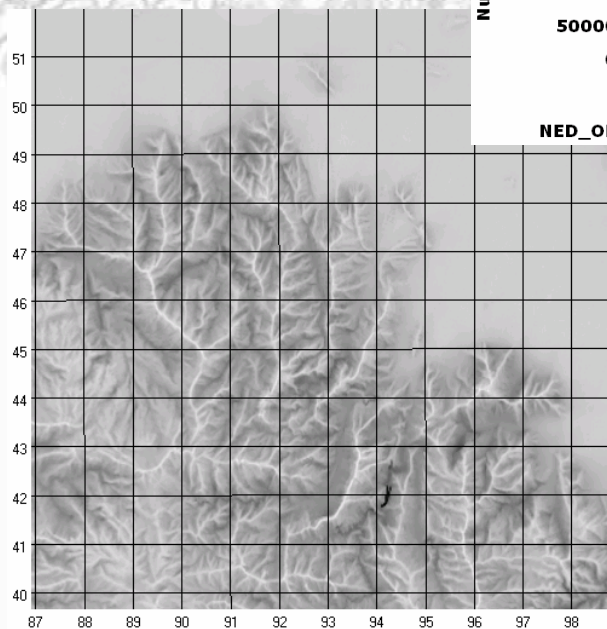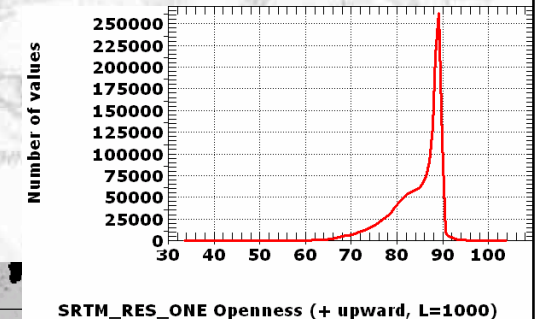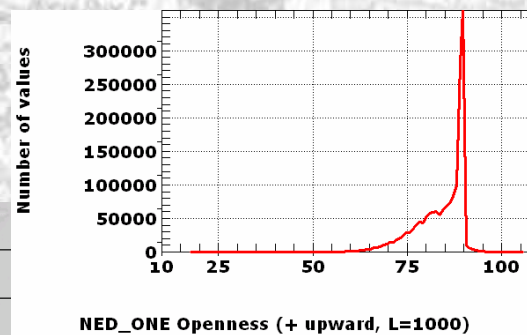
Maximum Curvature

NED
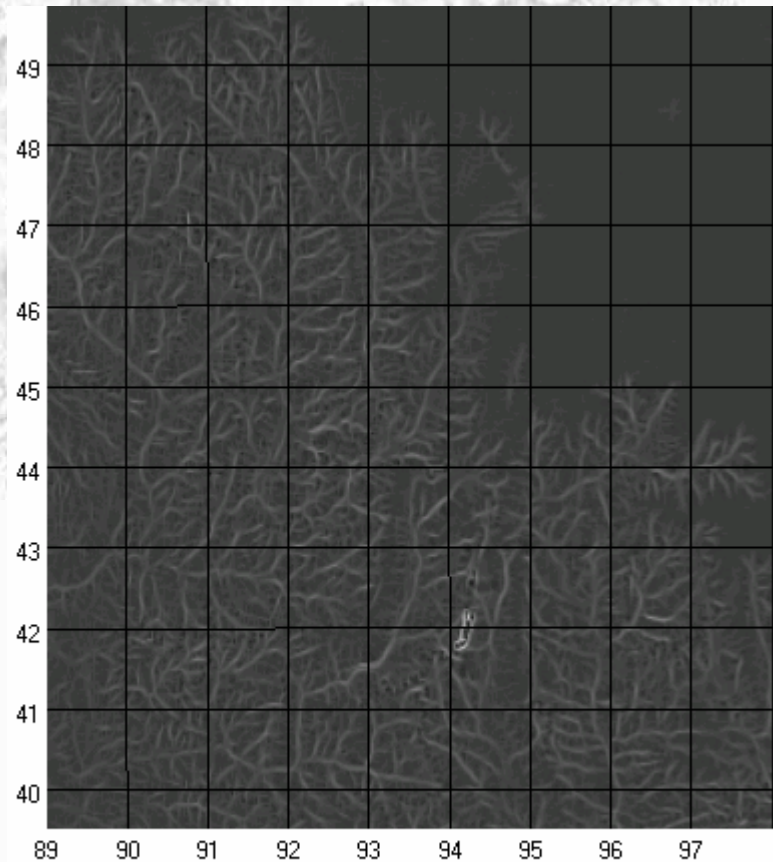
SRTM
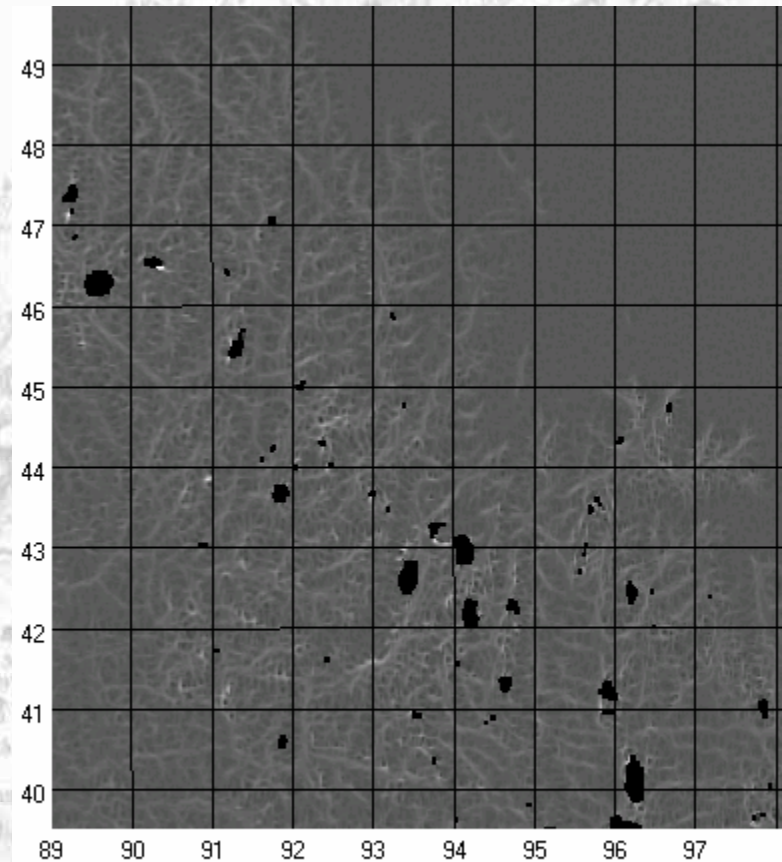
Practical Application of Geomorphometry

Optimal Sensor Location

•**Green fan sees 29% of potential area**

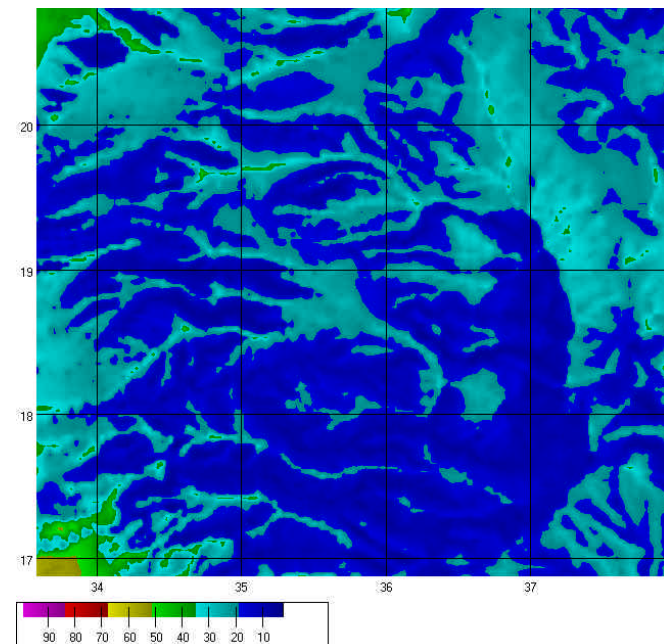•**Orange fan sees 20% of potential area**

Distribution of Viewsheds
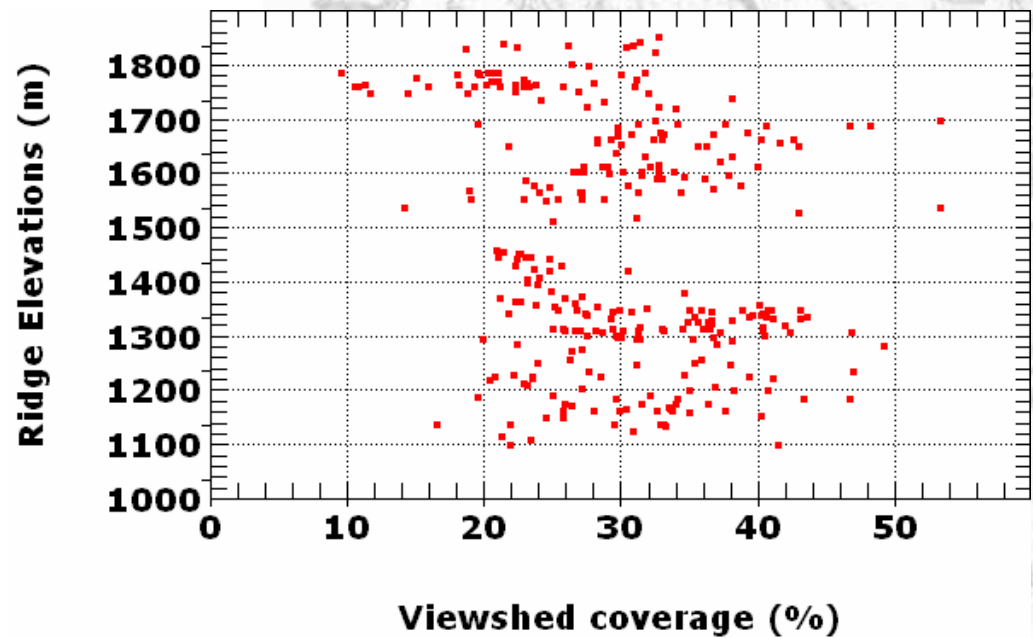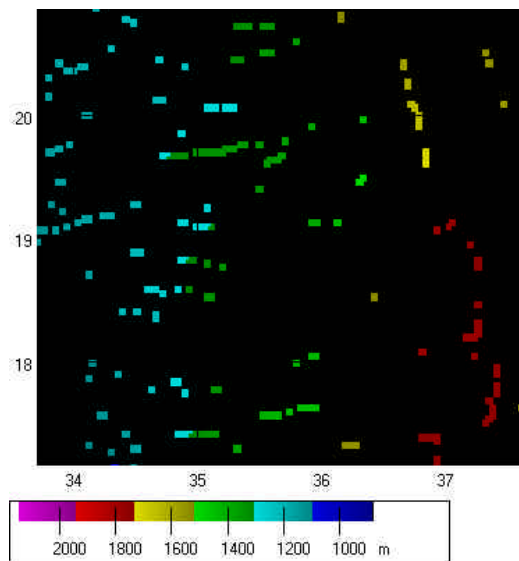
Viewshed Coverage
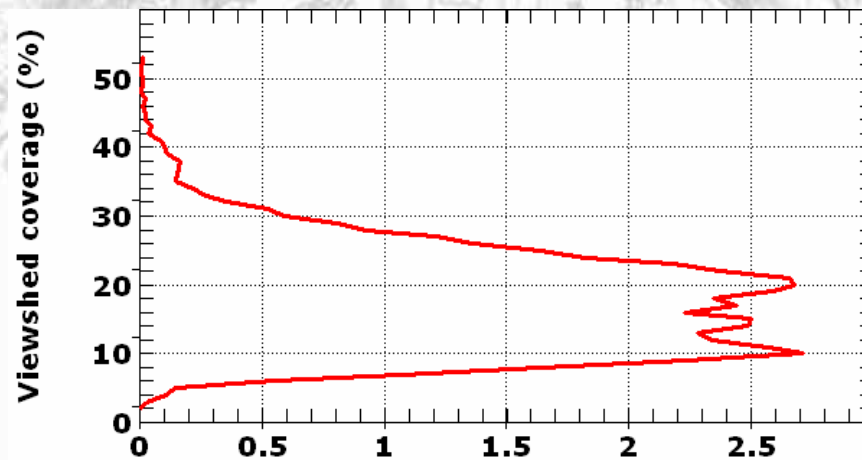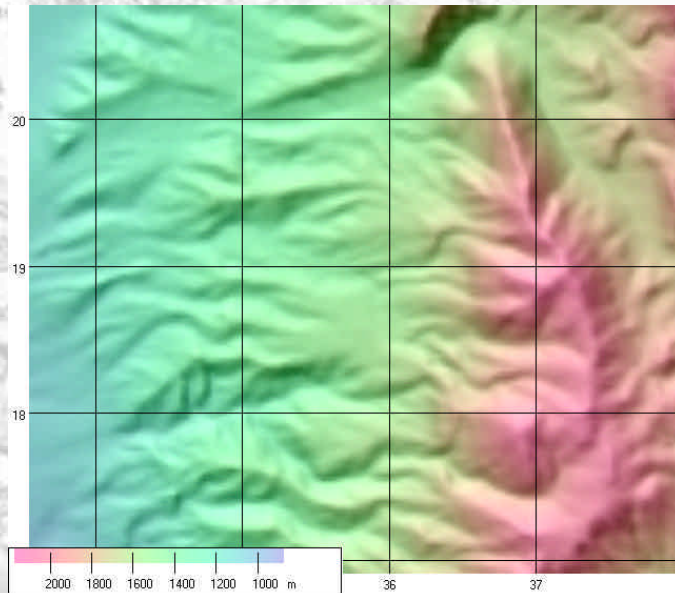
Exhaustive search, very expensive
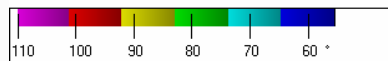
Very few sites with >35% viewshed coverage

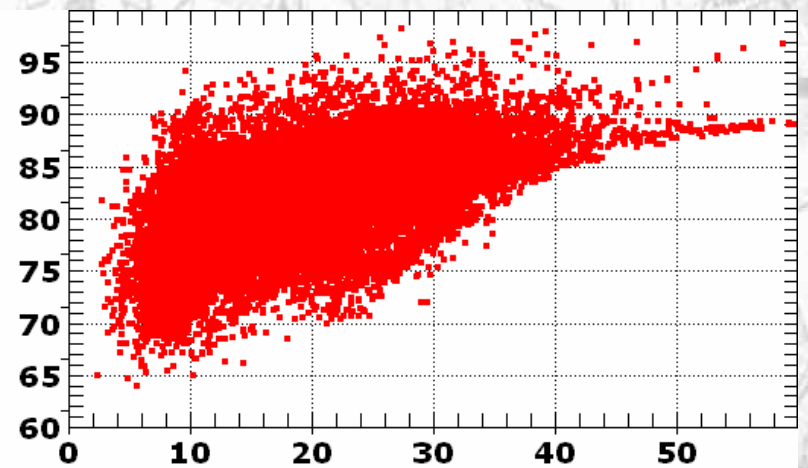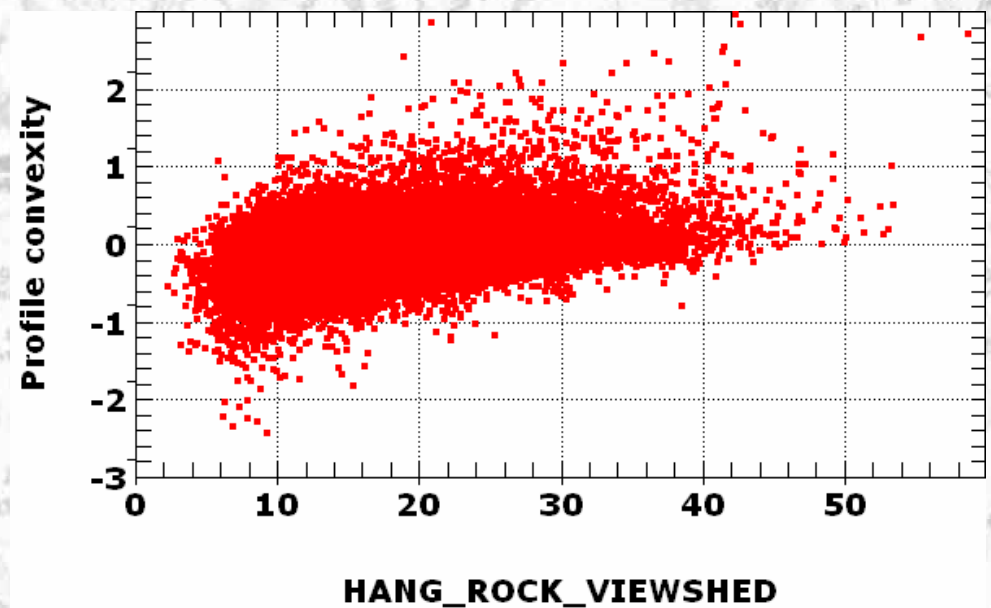# Viewshed Coverage from Ridges

Ridges

Upward Openness & Viewsheds
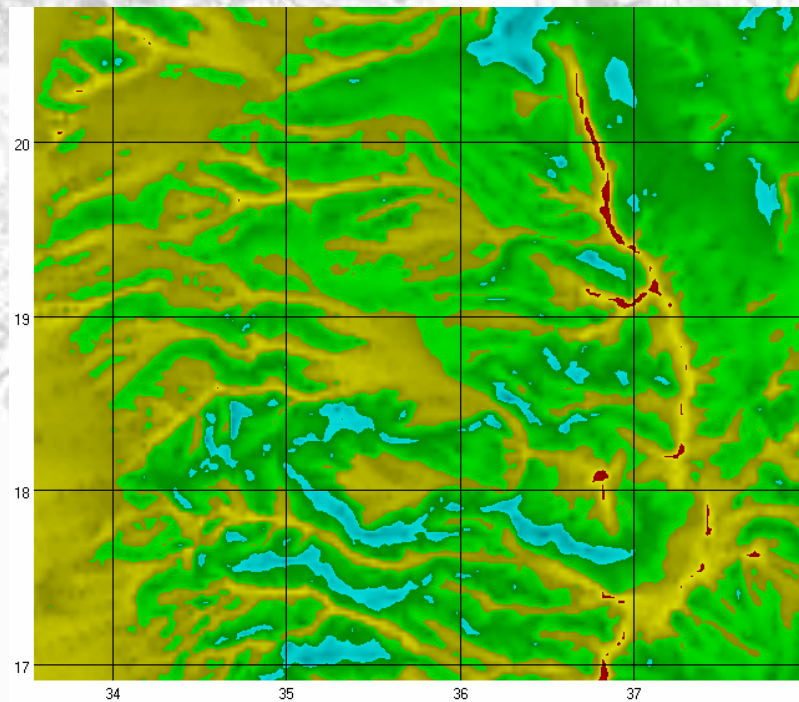
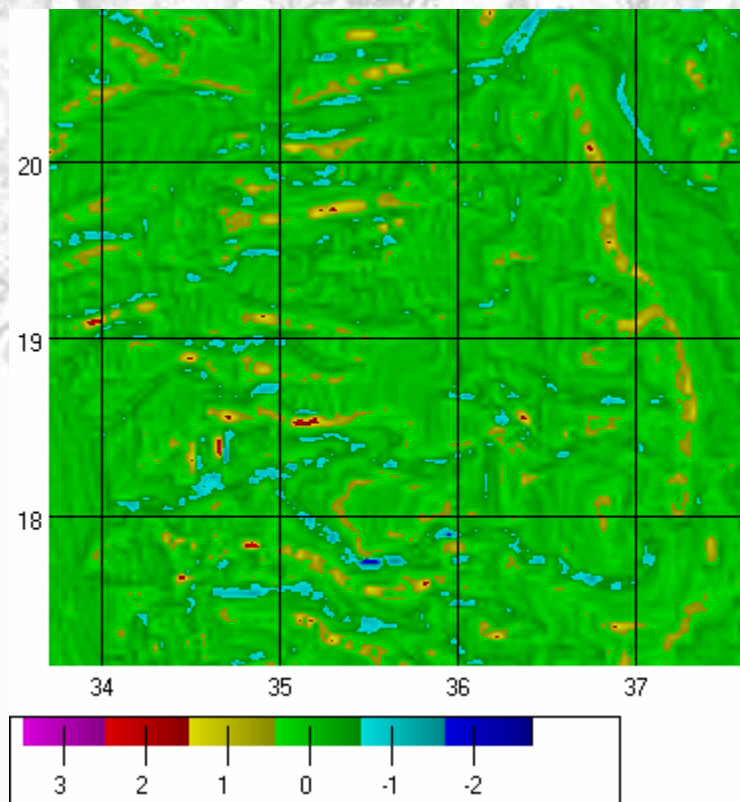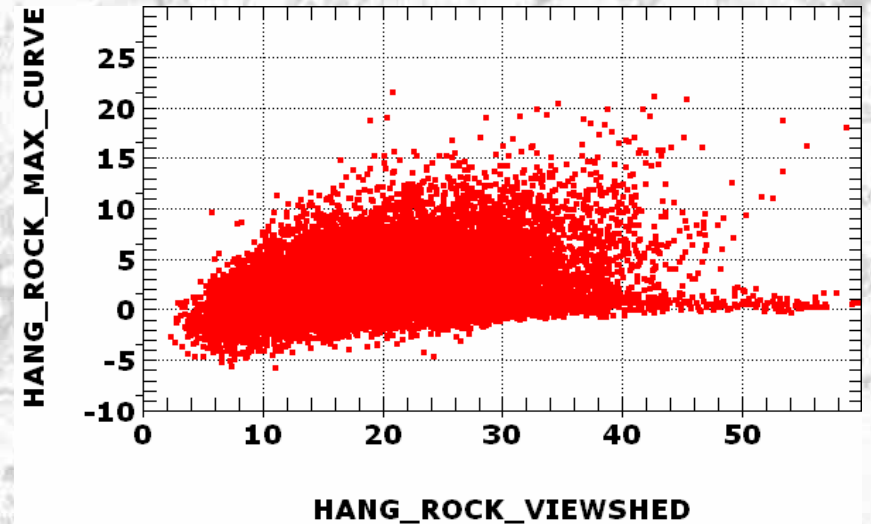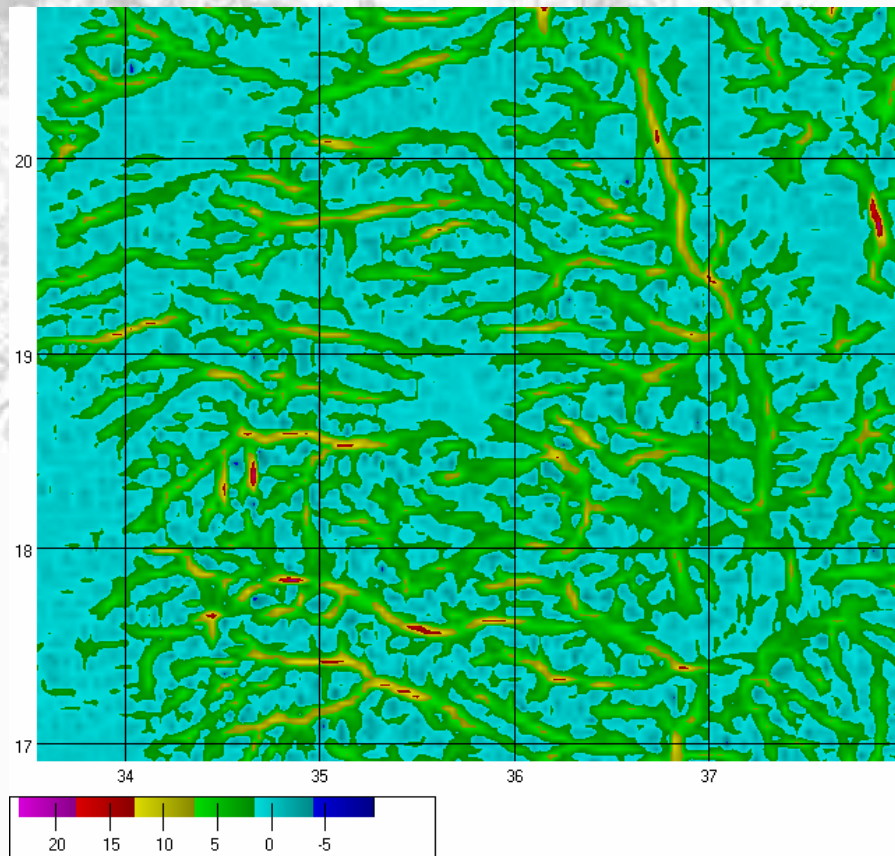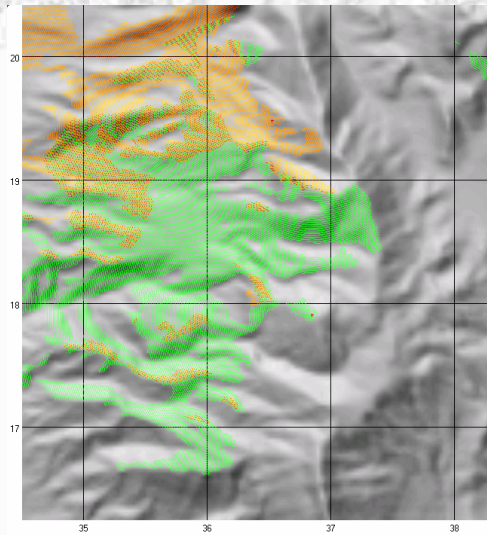# Profile Convexity & Viewsheds
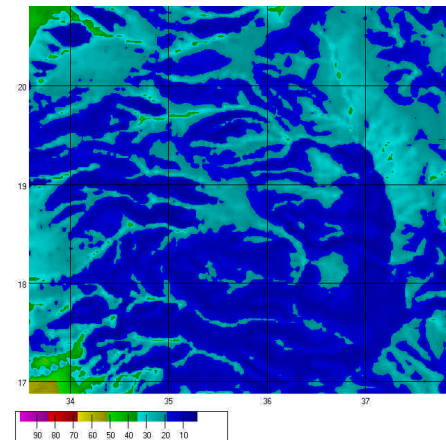
Maximum Curvature & Viewsheds

Optimal Sensor Location

- **Combine geomorphic variables for potential locations**

- **Curvature and openness likely to be best**

- **NED demonstrably better than SRTM for these**
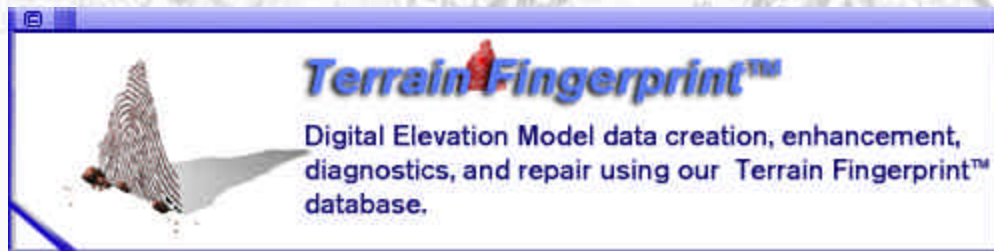

Viewshed Coverage

Conclusions

- **Systematic differences in many terrain parameters computed from NED and SRTM**

- **Slopes from SRTM differ from NED, and are critical for many applications**

- **1" SRTM matches NED more closely than 3"**

- **3" averaged and thinned SRTM have very similar statistics**

- **DEM quality control issues affect geomorphometry statistics**

Programs Used

- http://www.usna.edu/Users/oceano/pguth/website/microdemdown.htm
- freeware

- http://www.nsiworldwide.com/
- free demo